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THE
PRINCIPLES
OF
AGRICULTURE

BY

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School of Agriculture, Cambridge

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PREFACE

This is the first volume in a new series written specially to meet the needs of Farm Institute students. There is a lack of suitable textbooks at this level of agricultural education by comparison with the number of textbooks available for university students, and with the books on farming that have been published for use in schools. The aim of this volume is to give a simple yet accurate account of the principles underlying agriculture, and the other volumes in the series are planned to give a more detailed treatment of the different aspects of agriculture that are dealt with here in outline.

It is a venture into a previously neglected field, with little or nothing to act as a guide. The series represents certain views as to the type of course to be given at Farm Institutes on the assumption that the course would extend over one year, and would be designed to meet the needs of those who have been aptly described as the 'non-commissioned officers' of the industry. The sciences are treated as a part of a central theme of agriculture, and at every point an attempt is made to bring out the practical implications of the scientific principles involved. To use this book as the basis of a course at a Farm Institute implies little or nothing in the way of laboratory work for students, though the teacher could add to the value of the book by the use of suitable material for demonstration. No suggestions are made on this, because the greatest value in teaching comes from the use of local material. As the type of farming varies from one county to another, so a different emphasis must be placed on the subject matter.

Part I gives a simple factual description of the farming of England and Wales as it was in 1939, and is illustrated by maps showing the distribution of crops and stock on a county basis. Provision is made in all tables for the insertion of up-to-date figures, and these alone should give valuable teaching material. It may be possible for Farm Institutes to prepare detailed maps of their counties to illustrate on a local scale the factors influencing the practice of agriculture. The individual figures for every county are published in an appendix. In course of time, Farm Institutes could compile a valuable set of records of the changes taking place in the agriculture of the counties they serve. In this way, the practical teaching on the Institute Farm would be given against the background of farming in the county, and that in turn would be related to the national condition of farming.

Parts II and III are, as their titles imply, devoted to the principles of crop and animal production. These two parts are intended to serve as an introduction to the two volumes to appear in the series dealing with Crop Husbandry and Stock Husbandry. The subject-matter of these Parts would probably occupy the first of the three terms, the two later terms being used for a more detailed study of crop and stock husbandry.

Part IV is perhaps the greatest experiment in this volume. It deals with farming as a business, and even at university level there are scarcely any books on the subject published in this country. The economic principles of farming and the difficult subject of farm management are described in simple language. It is in this part that the teacher's interpretation, with local considerations taken into account, is likely to be of the greatest benefit.

Agricultural science is becoming increasingly a subject for specialists, and there has been a constant feeling of presumption in attempting to write on the principles of agriculture that impinge on so many specialist fields. But whatever might have been the advantages of a textbook written by a number of specialists under the guidance of an editor, it might have been difficult to achieve the uniformity of treatment that it is hoped has been attained in the present work.

My task has been greatly eased by my colleagues at the School of Agriculture, who have given generously of their time to assist me. My special thanks are due to Mr. F. Hanley for much wise counsel and helpful criticism at all stages in the production of this volume, and my thanks are also due to Dr. Carson, Dr. Dillon Weston, Mr. Halnan, and Dr. Menzies Kitchin for their comments on special chapters.

I should greatly value any comments or suggestions, particularly from teachers in Farm Institutes, who may be using this as a text-book. It may be premature to consider future editions, but suggestions for improvements are welcomed and will be used if the occasion arises.

Ronald Ede.

School of Agriculture,
Cambridge.

February, 1945.

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FARMING IN ENGLAND AND WALES

CHAPTER I

THE OBJECTS OF FARMING

THE term farming is used to embrace all the activities concerned with the cultivation of the land for the production of crops and stock. Its primary object is the provision of a supply of food, and for this reason it is one of the basic industries of the world. Its origins are lost in history, but the development of civilization and the changes that have taken place since man lived in a state of barbarism have been closely related to, and mainly dependent upon, the improvements in farming as a means of food supply. Uncivilized peoples relied for their food on the gathering of wild fruits and seeds and the killing of wild animals and birds. Such a form of living was uncertain and precarious, and the first change to take place was the taming of certain types of wild animals, notably cattle and sheep. These were kept in herds and flocks, and the people moved from place to place in search of pasturage for their animals. In time, the wandering tribes started the cultivation of land to give additional food for themselves and for their animals, and this led to the formation of settled communities of people. In this way, they were assured of a more certain supply of food, but the crops they grew were mostly cereals, and they were still exposed to the risks of food shortage because of unfavourable seasons.

SUBSISTENCE FARMING ON THE MANOR

After the Norman Conquest, farming in the British Isles was organized on the basis of settled communities, each community being known as a manor. The manors corresponded in size to the parishes of to-day, and each manor was a self-supporting community. The object of farming was a supply of food and the production of wool to provide clothing. Purchases were small and consisted chiefly of iron for implements, and salt for the preservation and flavouring of food. The crops grown were wheat or rye for bread, and barley for bread or for brewing, and the rotation was winter corn, spring corn, and a bare fallow. This gave a supply of grain for use in the winter, but there was a serious lack of winter food for stock. To meet this difficulty, large numbers of livestock were killed in the autumn and preserved in salt for consumption during the winter. The only animals kept alive through the winter were those needed for

breeding purposes the following spring. There were no external sources of food, and a bad harvest meant a serious shortage of food during winter. Added to this, the seasonal nature of food production made it difficult to have a regular supply of food at all times of the year. It was in the few months after harvest that food was most plentiful, and the ancient custom of rejoicing at harvest is associated with this period of comparative abundance. Farming of this nature is described as subsistence farming, the object being the subsistence, or the support, of the farmers and their families.

Transition to Farming for Profit

Since the time of the manorial system there has been, in the British Isles, a gradual transition from subsistence farming to a system of farming for profit; but even under modern conditions most farms provide a proportion of the food required by the farmer and his family, in addition to the produce grown for sale. Throughout the world, by far the greater proportion of farmers is engaged in subsistence farming, especially in parts of the world where there is a large population of peasant farmers, as in India and China. It is only within the last hundred years that in certain countries, for example Canada, the United States of America, Argentina, Australia, and New Zealand, farming has been organized primarily for the production of food for export.

The transition in the British Isles has been associated with the industrial development of the country. The first sign of the change came at the end of the fifteenth century, when an expansion of the wool trade of the country led to an increase in the price of wool and encouraged farmers to take up sheep farming in place of crop production. The second important period of change came in the eighteenth century, following the introduction of root and clover crops. These new crops greatly improved the productivity of British farming and provided a supply of food for the urban population which increased rapidly after the Industrial Revolution. In the last 150 years, the growth of industry has resulted in a demand for food greater than can be supplied by the home producer, and the British Isles have become one of the world's largest markets for food, and receive supplies of many kinds of food from countries with a surplus for export.

Farming and The Production of Food

Farming in the British Isles under conditions of peace is concerned with the production of crops and livestock to supply a part of the food requirements of the country. Farms are no longer organized mainly with a view to producing food for the household, and the first objective of the farmer is to make a money income.

The two main sources of income are the sale of crops that are used as food, and the sale of livestock as meat, or of their products, such as milk and eggs. In some cases, an income is made from the sale of a farm product that serves as a raw material of a manufacturing industry ; as an example, flax is grown in certain parts of the British Isles and used for the making of linen.

The majority of farmers in the British Isles pursue a policy known as mixed farming, which combines the production of crops and livestock. The relative importance of crops and stock in the organization of any particular farm varies according to circumstances. In some cases crops occupy a major position with subsidiary livestock enterprises, and in others the livestock assume the greater importance. Under certain special conditions, there are farms entirely dependent upon the sale of crops, with no livestock, and farms whose only source of income is from stock. In order to understand the policy of a farm, it is necessary first to discover whether the farmer derives an income mainly from crops, mainly from stock, or from a more even balance of the two.

Crops that are grown and sold for human consumption may be defined as cash crops. The specialized forms of farming, such as market gardening and fruit growing, are entirely concerned with cash crops that are sold for direct human consumption. Of the general farm crops, the important cash crops are wheat, barley, potatoes, and sugar beet, and, in some districts, oats may be a cash crop. A farmer may decide to rely on one of these cash crops as his principal source of income, but he cannot specialize on that one crop to the complete exclusion of all others without taking a serious risk of ruining his farm. If the same crop is grown year after year on the same piece of land, there is certain to be a loss of fertility and an increase in the incidence of disease, and with certain types of crops weed infestation becomes a serious problem. Moreover, a concentration on one crop makes it difficult to achieve the economic employment of labour throughout the year.

Designing a Rotation

The most important reason for growing a selection of crops is to maintain the fertility of the soil, which, under the conditions prevailing in the British Isles, is achieved mainly by the use of farmyard manure. For this purpose, a farmer relying for his main source of income on one cash crop, grows a selection of different crops and also keeps some form of livestock. The livestock in turn must be provided with food, and whilst to some extent they feed on by-products from cash crops, special crops may have to be grown for their needs. This close relationship between cropping policy and stocking policy may be illustrated by an example. A

farmer who wishes to grow potatoes as his main source of income has to decide what proportion of his land he can devote to the crop with due safeguards for the fertility of his soil. One of the requirements for the growing of potatoes is a supply of farmyard manure. For the making of farmyard manure, he has to keep some form of livestock, and for them he requires straw, and must grow a cereal crop. He requires food for his stock during the winter and decides that the cheapest form of winter food is hay, from a mixture of ryegrass and clover. He also requires a quantity of straw for the clamping of his potatoes, and calculates that, to meet his needs of straw for his livestock and for clamping, it is necessary to grow two acres of cereal for every acre of potatoes. Thus he finds that to grow one acre of potatoes every year, he needs two acres of cereals and one acre of ryegrass and clover. He arranges these four crops in a convenient sequence and decides to grow wheat as an autumn sown cereal, and follow this with potatoes, which receive an application of farmyard manure. He grows barley after the potatoes, and undersows the barley with a mixture of ryegrass and clover to give a hay crop the next year, and the remains of this crop are ploughed in for the benefit of the wheat. This sequence of cropping is called a rotation, and it is not only necessary for the growing of potatoes, which was the first objective, but maintains the fertility of the soil, makes full use of by-products, and provides additional sources of income. It also enables work to be found for labour at most seasons of the year. This rotation is an adaptation of the famous Norfolk four-course rotation, which was developed in the eighteenth century by combining the old manorial rotation of cereals with the newly introduced root and clover crops. This was the first system of farming to effect a combination of crops and stock and is probably the greatest single improvement that has ever been made in British farming practice.

On a farm devoted primarily to the production of cash crops, livestock are a subsidiary part of the organization and are kept for the dual purpose of consuming by-products and treading the straw into farmyard manure. The type of livestock kept on a farm producing cash crops depends to some extent upon the by-products available, but the most useful form of livestock is cattle, which live in yards during the winter months. In some cases, young cattle are bought in the autumn and are kept during the winter on a ration consisting mainly of hay, straw, and roots. The ration is sufficient to keep the animals growing but not to fatten them, and they are sold the following spring as stores to be fattened on a grass farm during the summer. In other cases, older cattle are bought in the autumn and given a more concentrated ration that

will fatten them, and they are sold as beef cattle when they are fit for slaughter. Both methods involve the utilization of considerable quantities of straw and result in the production of a large amount of farmyard manure. With the possible exception of the purchase of concentrated cake for the fattening animals, the food required comes from crops grown on the farm. Pigs and sheep are forms of livestock kept for the consumption of certain by-products. One by-product from sugar beet consists of the tops, which can be consumed on the field by sheep, or carted off and fed to cattle. The by-product from the growing of potatoes, consisting of small and damaged tubers, is frequently disposed of as food for pigs.

A farmer who obtains the major part of his income from the sale of livestock and livestock products builds up his farm organization with crops as the subsidiary enterprise. The natural food for livestock is grass, and where a farm consists entirely of grassland the only source of income is from the sale of livestock or their products. Under pre-1939 conditions, there were many farms in this country on which all the land was devoted to the growing of grass, and any foodstuffs needed to supplement the grass were bought in the form of concentrated meals and cakes. In other cases, a part of the farm was under the plough and the main purpose of the ploughland was the production of crops to be fed to stock. This policy of feeding stock on home-grown feeding-stuffs was adopted very widely under conditions of war, when supplies of imported foods were drastically curtailed. The principal crops grown for stock are the fodders, consisting of kale, lucerne, sainfoin, and clovers, and the root crops, the most important being turnips, swedes, and mangolds. Of the cereal crops, oats are most widely grown as food for stock, and barley that is not up to the standard of malting quality is used for feeding to stock, particularly pigs. In periods of low prices, wheat may be not sold as a cash crop but fed to livestock and marketed indirectly as meat or milk. Beans and peas are crops grown primarily for consumption on the farm, especially as a source of protein in the rations of farm animals. As with the farmer growing cash crops, the farmer producing home-grown feeding-stuffs arranges the crops he wishes to grow in a convenient sequence, or rotation, and it is often possible to include in the rotation a small acreage of a cash crop, partly to balance the rotation and partly to provide an additional source of income.

Livestock as a Major Enterprise

There are many forms of livestock production that may be adopted as the major enterprise on a farm. Of these, the most important is the production of milk for sale, and on a dairy farm it

is usual to find the cropping policy entirely subordinated to the needs of the dairy herd. In districts where most of the land is devoted to grass, other forms of livestock enterprise, such as beef production or the raising of store cattle, may be the main source of income. In hilly and mountainous districts, which provide only rough and poor grazing, the main form of livestock kept is special breeds of mountain sheep. There are some cases of specialized farms devoted to the keeping of pigs or poultry where little or no part of the food is produced from the land. These are extreme cases of specialization, and are organized on the lines of a factory, the raw materials in the form of food being purchased, and the sales consisting of pigs for pork or bacon, and of eggs or table birds.

Formulation of Farming Policy

Thus the object of farming is ultimately the production of food, and to achieve this every individual farmer must find the best combination of cropping and livestock policies to suit the circumstances of his farm. In formulating a farming policy, due attention must be paid to the markets available and to the safeguards necessary to maintain soil fertility. The most important considerations in deciding on the policy for a farm are the soil and its character, and the climate of the locality. The effects of soil and climate on farming policy are discussed in greater detail in a later chapter.

Chapter 2

THE SIZE OF THE FARMING INDUSTRY

THE great industrial developments that have taken place during the last 100 years have tended to obscure the importance of farming in England and Wales, and it is only during periods of war that full credit is given to farmers for the part they play in providing food. The figures given in this chapter are taken from the agricultural returns collected on 4th June, 1939, and show the size of the industry in respect of acreage of land, value of output, and numbers of people employed.

Area of Farming Land

The land available for farming purposes is returned under the three headings of arable land, permanent grassland, and rough grazings, and the following table shows the acreages of these three types of land in England and Wales in 1939.

TABLE I

ACREAGES OF ARABLE LAND, PERMANENT GRASS, AND ROUGH GRAZINGS IN ENGLAND AND WALES

	1939	19
	acres	acres
Arable Land	8,934,000	
Permanent Grassland	15,709,000	
Rough Grazings	5,608,000	
Total	30,251,000	

The most important conclusion to be drawn from these figures is the predominance of grassland, and from the diagram given in Fig. 1 it will be seen that 70 per cent of the land is classified as permanent grass and rough grazings. On these types of land, livestock farming is of major importance, and contributes most, if not all, of the income derived from the use of the land. Of the arable land, less than half the acreage is used for the production of crops for direct sale, and the remainder is used for crops fed to livestock, and marketed indirectly in the form of livestock products.

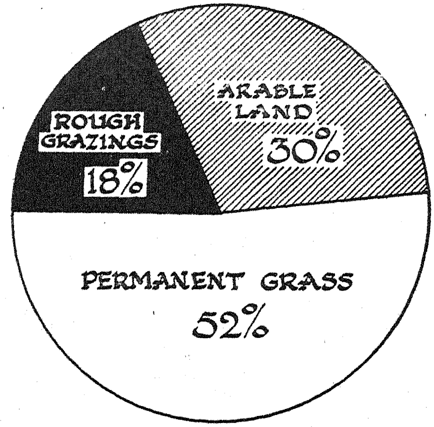


FIG. 1. THE PERCENTAGES OF ARABLE LAND, PERMANENT GRASS, AND ROUGH GRAZINGS IN ENGLAND AND WALES IN 1939

THE OUTPUT OF FARMING

The outstanding importance of livestock in the farming of England and Wales is shown in the following table, which gives the money output obtained from the sale of crops and livestock in 1938-9.

TABLE 2

VALUE OF AGRICULTURAL OUTPUT OF ENGLAND AND WALES 1938-9

	1938/9		19 /	
	VALUE	PERCENTAGE	VALUE	PERCENTAGE
Livestock and Livestock Products . .	£154,560,000	70·0		
Farm Crops . .	£31,800,000	14·5		
Fruit, Vegetables, Flowers, etc. . .	£33,070,000	15·5		
Total	£219,430,000	100·0		

These figures show clearly the extent to which the farmers of England and Wales depend on the sale of livestock and livestock products for their income. The predominance of livestock is due to two main factors. The first is climatic, the rainfall in most parts of England and Wales being favourable for the production of grass and green fodders. The second factor is associated with the decline that has taken place in the arable acreage since 1870.

During this period, the prices of cereals have fallen, and farmers have been unable to produce these crops in competition with the supplies imported from countries more suitable for their production. The arable land has been put down to grass, and livestock production has taken the place of cereal growing; though there are large imports of meat, there is no competition from overseas in the production of fresh milk. The change in the character of farming is also reflected in the proportion of income derived from fruit, vegetables, and flowers. Supplies of some of these are imported, but the more perishable types of these products cannot compete in freshness with those produced at home.

The following table shows the extent to which the United Kingdom was dependent upon home-produced supplies and imports respectively for some of the more important foods.

TABLE 3

PERCENTAGE OF CERTAIN FOODSTUFFS IMPORTED AND HOME PRODUCED IN THE UNITED KINGDOM—AVERAGE OF THE TWO YEARS 1934 AND 1935

TYPE OF FOODSTUFF	1934 & 1935		19	
	IMPORTS PER CENT	HOME PRODUCE PER CENT	IMPORTS PER CENT	HOME PRODUCE PER CENT
Flour	87	13		
Meat (including Bacon) ..	51	49		
Milk	—	100		
Cheese	69	31		
Eggs	39	61		
Fruit	77	23		
Potatoes	3	97		
Other Vegetables	25	75		
Sugar	73	27		

Number of Workers

The number of people employed in farming in England and Wales in 1939, apart from farmers and their wives, was 607,000, made up of 534,000 male workers and 73,000 female workers. Of this total, 511,000 were classified as regular workers and 96,000 as casual workers. The proportion of casual workers is nearly one-

sixth, and this is an indication of the seasonal character of some types of farm work, especially harvesting and fruit picking. The number of farmers is not given in the agricultural returns, but returns were made for 362,000 holdings. The number of farmers is probably fewer than the number of farms; but when account is taken of the number of farmers' wives who assist on farms, the total is more than one million people employed and occupied in farming. There are few separate industries in England and Wales employing a greater number of workers and in the census of 1931 farming was the fourth largest employer of labour, and the number in agricultural occupations was only exceeded by those classified as metal workers, those engaged in transport and communications, and those in various commercial occupations such as shopkeepers and salesmen.

Size of Farm

One important factor in the organization of farming is the size of the holding, and the following table shows the numbers of holdings in England and Wales in different size groups in 1939.

TABLE 4

NUMBER AND SIZE OF AGRICULTURAL HOLDINGS IN ENGLAND AND WALES, 1939

SIZE GROUPS	NUMBER OF HOLDINGS, 1939	PER CENT OF TOTAL	NUMBER OF HOLDINGS, 19	PER CENT OF TOTAL
Above 1 acre and less than 5 acres	61,384	17·0		
Above 5 acres and less than 50 acres	161,035	44·5		
Above 50 acres and less than 100 acres	61,348	17·0		
Above 100 acres and less than 150 acres	31,804	8·5		
Above 150 acres and less than 300 acres	34,228	9·5		
Above 300 acres	11,864	3·5		
Total	361,663	100·0		

It will be seen that more than 60 per cent of the holdings in England and Wales were less than 50 acres in extent, and that the most numerous size group was that between 5 and 50 acres. The counties with the greatest number of farms in the largest size group

were Norfolk with 736, Northumberland with 641, Lindsey division of Lincolnshire with 640, Essex with 535, the East Riding of Yorkshire with 508, Wiltshire with 487, and Hampshire with 445. Large farms are generally associated with arable farming on the lighter types of soil, and most of these counties have large areas of this nature. Smaller farms predominate in grassland and dairying districts, and on the more valuable and fertile soils.

Chapter 3

FACTORS INFLUENCING FARMING PRACTICE

THE most important factor influencing the type of farming practised in a district is the climate, as this determines the amount of warmth and moisture available for plant growth. The climate of a country or a district may be described as the average state of the atmosphere in respect of warmth, moisture, and wind over a long period of time. The term 'weather' is used to describe the daily changes that take place in atmospheric conditions. Farming has to be carried on with due regard to the limitations imposed by climatic conditions, and although the farmer can, to some extent, mitigate the effects of too much or too little moisture, or of excessive heat and cold, he must ultimately adapt his system of farming to the climate.

Climate : Rainfall

The uncertainty and variability of the climate of England and Wales are proverbial, and any attempt to describe the climate, which should reveal the average state of the weather, cannot take full account of the variability, not only from one year to another, but even within a single year. The greatest variation in climate as between districts is in the amount of annual rainfall, and there are smaller variations in respect of temperature. The map given in Fig. 2 shows the distribution of the annual rainfall over England and Wales, the figures being given in inches of rain. The greatest annual rainfall is in the west and north-west, and the areas of the highest rainfall are the mountainous parts of Wales and the Lake District, the Pennine Hills, and the hilly parts of Devon and Cornwall. In these districts, the average rainfall is between 40 and 60 inches a year, whilst in the more mountainous regions the rainfall exceeds 60 inches. The area with the highest rainfall in England and Wales is around Snowdon in North Wales, which has more than 200 inches of rain a year. Towards the flat country of the Midlands, the annual rainfall decreases, and there is a large tract of country with a rainfall ranging from 25 to 40 inches. In the east and south-east, there is an area with an annual rainfall of less than 25 inches.

There are two reasons for this distribution of rainfall. Firstly, the prevailing winds come from the south-west and west and, when they reach the west coasts, are full of moisture collected as they passed over the Atlantic Ocean. Secondly, these prevailing winds

make their first contact with land in the mountains and hills of the west, and the sudden cooling effect of the land causes the moisture to fall as rain. As the winds pass from west to east, they contain less moisture to fall as rain.

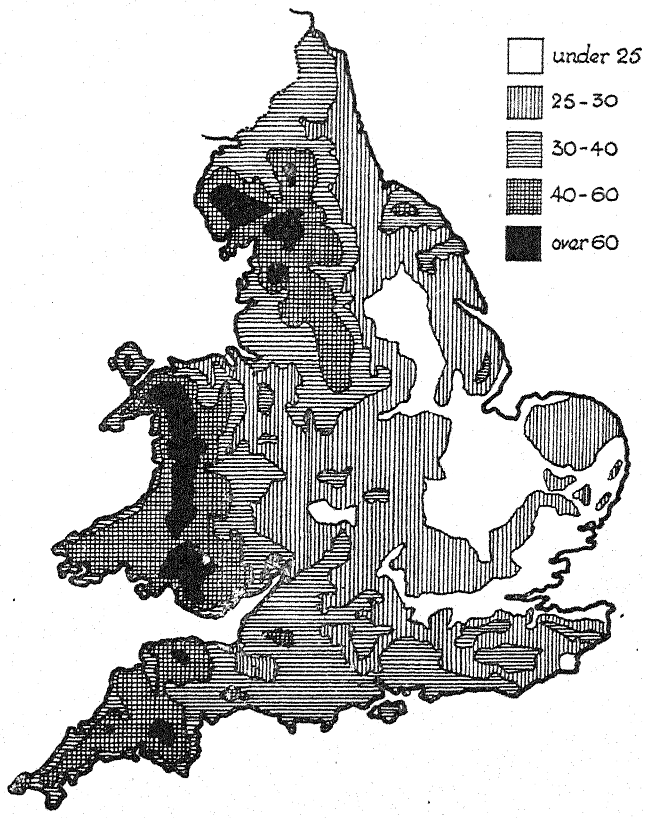
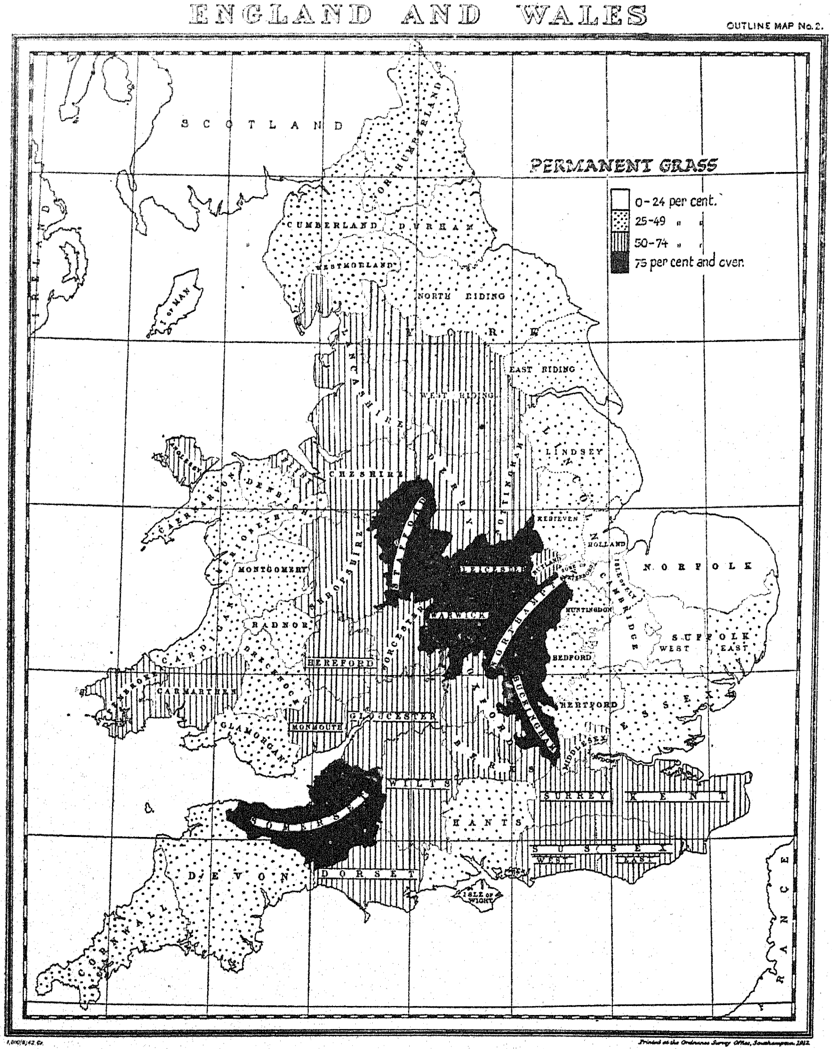


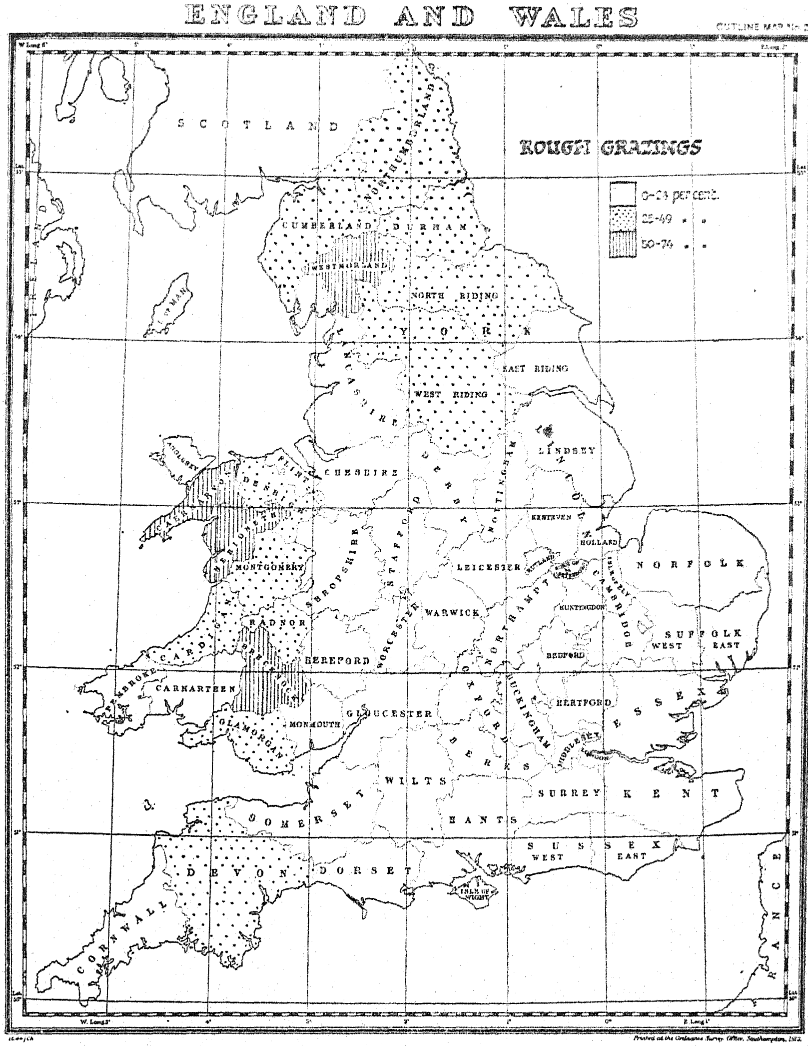
FIG. 2. THE ANNUAL RAINFALL OF ENGLAND AND WALES (IN INCHES)

The effect of the amount of rainfall on the type of farming is seen by a study of the maps given in Fig. 3 and Fig. 4. These maps show the distribution of permanent pasture and rough grazings in 1939. The area with the greatest proportion of permanent grass comprised the counties of Stafford, Warwick, Northampton, Leicester, and Buckingham, all of which had more than three-quarters of their total agricultural land devoted to permanent grass. It will be noted that these five counties are in an area with an annual rainfall of more than 25 inches. The proportion of permanent grass decreased in the areas of lower



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 3. THE DISTRIBUTION OF PERMANENT GRASS IN ENGLAND AND WALES IN 1939, IN RELATION TO THE TOTAL ACREAGE OF AGRICULTURAL LAND (INCLUDING ROUGH GRAZINGS)



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 4. THE DISTRIBUTION OF ROUGH GRAZINGS IN ENGLAND AND WALES IN 1939, IN RELATION TO THE TOTAL ACREAGE OF AGRICULTURAL LAND (INCLUDING ROUGH GRAZINGS)

rainfall towards the east and north-east, and also in the areas with a rainfall approaching 60 inches a year. In the latter case, the permanent grass is replaced by a higher proportion of rough grazings, due in part to an excessive rainfall for good quality grassland and in part to the more mountainous and exposed character of the country.

Climate : Temperature

Some indication of the variation in the amount of warmth can be obtained by comparing the average temperatures of a district for the months of January and July. The map given in Fig. 5 shows the distribution of temperatures in England and Wales for these two months. It is important to remember that these figures

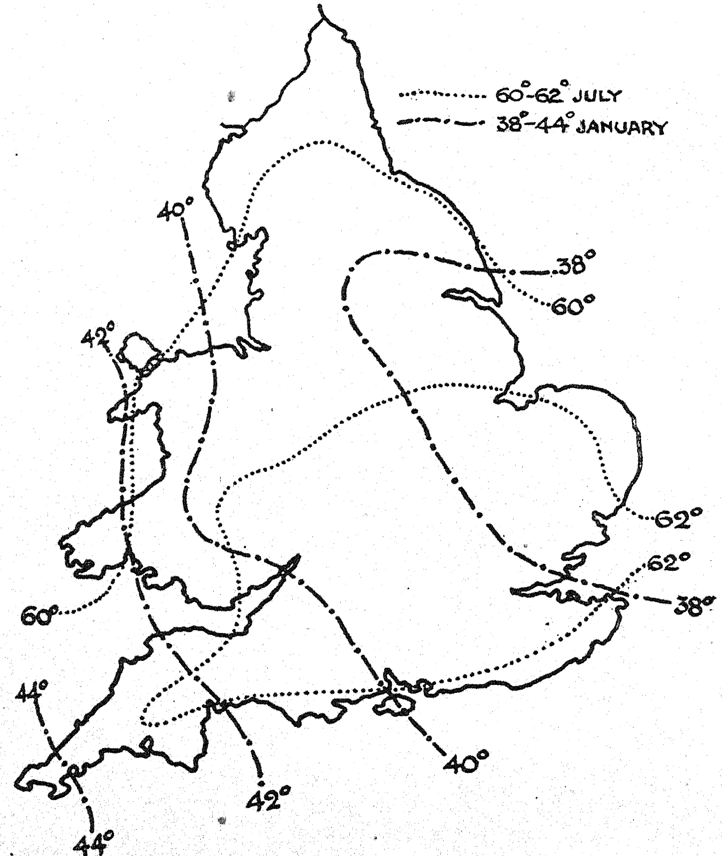
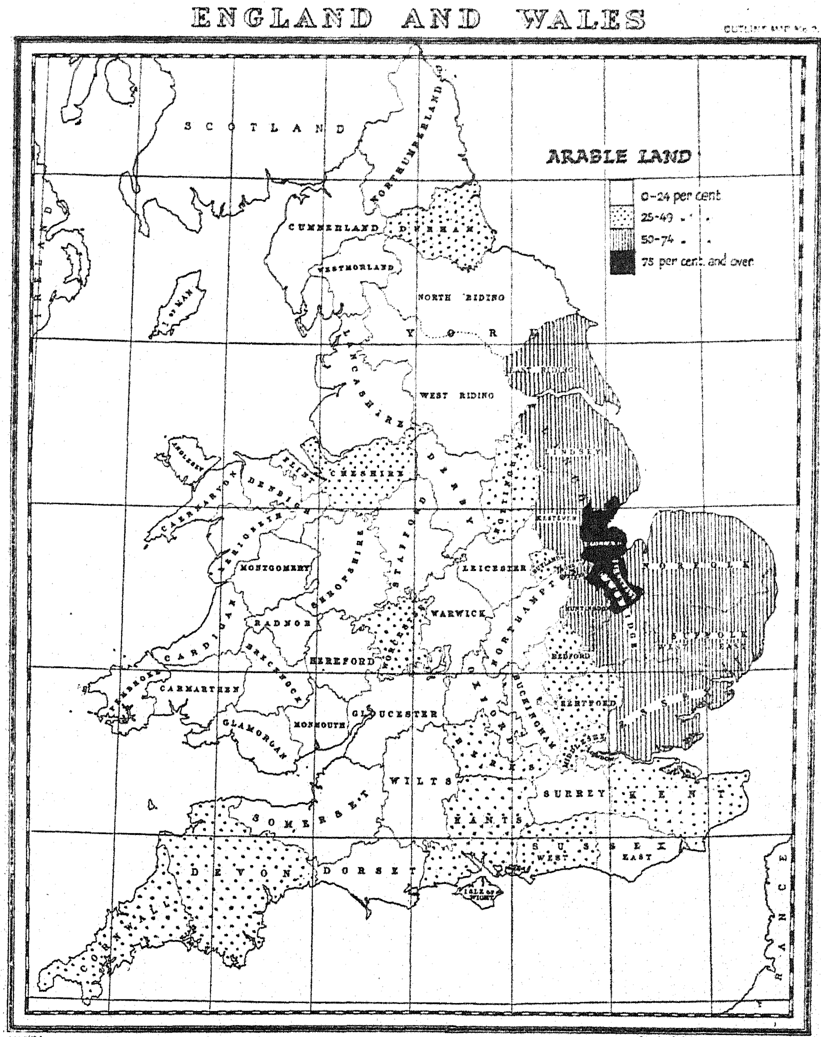


Fig. 5. The January and July Isotherms in England and Wales



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 6. THE DISTRIBUTION OF ARABLE LAND IN ENGLAND AND WALES IN 1939, IN RELATION TO THE TOTAL ACREAGE OF AGRICULTURAL LAND (INCLUDING ROUGH GRAZINGS)

are average temperatures and do not show the highest and lowest temperatures that may be experienced in any district. From the map it will be seen that, in winter, the temperature decreases from the west to the east. In the extreme west of Cornwall, the average temperature in January is 44°F., whilst there is a large area in eastern England with an average January temperature of 38°F., a difference of 6°F. This range from west to east is due to the fact that, in winter, the west coast is under the influence of warm sea currents, whilst the east coast is likely to be more affected by masses of cold air spreading from the continent of Europe. During the summer months, the temperature rises from north to south. Except in the north of England, the whole country has an average July temperature of at least 60°F., and there is a large area stretching from Somerset to Norfolk where the average July temperature rises to 62°F. Thus in parts of East Anglia there is a variation between winter and summer temperatures of 24°F., whereas in the extreme west of Cornwall the variation is only 16°F.

One of the critical factors in the effect of temperature on type of farming is the expectation of serious winter frosts, when the temperature drops below 32°F. It would be anticipated that in a district with an average temperature in January of 42°F. the number of days on which frost would occur would be fewer than in a district with an average temperature of 38°F. in January. This is borne out by the fact that at Falmouth, in Cornwall, the average number of days on which ground frost may be expected is 48, with little likelihood of frost in the months from May to September; while records for London, which lies in the 38°F. area, show that frost may be expected to occur on 101 days in the year, and that, over a long period of years, only the months of July and August have been completely free from frost.

Distribution of Arable Land

Some of the effects of temperature on the type of farming can be seen from studying the map showing the range of temperatures and comparing it with the map given in Fig. 6, which shows the distribution of arable land in England and Wales in 1939. The counties with the greatest concentration of arable land lie within the area having the lowest rainfall and the highest summer temperature. It is not only the low rainfall that encourages arable farming, but summer temperatures sufficiently high to ensure the adequate ripening of crops, especially the cereal crops. Moreover, in the drier areas of England and Wales, a considerable proportion of the rain comes with thunderstorms during the summer months, when, provided these are not excessively heavy, it makes the most useful contribution to plant growth. Consequently, there

is less rain in the winter months to interfere with the cultivation of the arable land.

For the growing of cereals in England and Wales, an average of 25 to 28 inches of rain is considered a reasonable figure, though wheat could be grown with a minimum of 20 inches a year provided that this falls at the times when it is most needed. Rain is most beneficial to a cereal crop in the spring, when the greatest amount of growth is taking place, and between the time of flowering and harvest, when the grain is filling. Grain crops, with the possible exception of oats, require an average summer temperature of at least 60°F. to ensure good conditions for ripening. A dry climate favours crops grown for seed and grain, and is also suitable for sheep, which suffer more from wetness than from cold in winter. A moist climate favours crops grown for their leaves, especially fodder crops, and the most suitable forms of livestock for this system of farming are bullocks and dairy cattle. In wet climates, the prevailing system of farming is grassland for the grazing of cattle for milk or beef production. Districts with a warm and 'early' climate are specially suited to market gardening. Such an area occurs in the far west of Cornwall, and in other districts, often near the coast, where, for local reasons of aspect or shelter from the north, specially favourable climates are experienced.

In general, lower temperatures, and cool climates, favour the growth of leafy crops, and swedes and turnips do particularly well under these conditions. In some respects, a cool climate has much the same effect as a wet climate and tends to favour a similar type of farming, with livestock predominating, and with grass as the most important crop. The temperature of a district is also associated with its height above sea level, and the temperature falls as the altitude increases. A rise in height of from 200 to 300 feet causes a drop in temperature of 1°F. This decrease in temperature influences the altitude at which certain crops can grow and ripen. Wheat is rarely grown in England and Wales at an altitude of more than 600 feet, though oats are grown and ripen at much greater altitudes. In England and Wales, the more hilly districts are in the west and north-west, and large areas are comparatively poor farming land and are classified as rough grazings. The map in Fig. 4, giving the distribution of rough grazings, shows the extent to which they are concentrated in Wales, and in the county of Merioneth 66 per cent of the land is classified as rough grazings.

Apart from the general considerations of the effects of climate, there are some factors of more local application. In some areas, the surface of the country is uneven and may result in a number of low-lying "pockets" or small valleys in which the temperature

at night falls more than on the surrounding higher land. Fruit growers, whose crops are susceptible to damage from late spring frosts, take care to avoid the planting of fruit in "pockets" of this nature. Aspect is another factor of some importance locally, and in hilly districts it often happens that cultivation can be carried to a higher altitude on the slopes that face the sun than on those facing north. In more exposed districts, wind may affect the system of farming, and precautions may have to be taken against damage to crops by wind. In some of the areas devoted to the growing of flowers in Cornwall, the fields are intersected with high hedges to protect the flower crops from the high winds that sweep in from the Atlantic. In other districts, wind may have a serious effect in years with a very dry spring by blowing away the surface of the soils, especially before it is covered by vegetation. Certain of the light soils in the fens of East Anglia are subject to blowing in some years.

Soil Type

The second important factor influencing the type of farming in a district is the character of the soil. There is a great variety of soils in England and Wales, but they can be classified into the five main types of clay soils, sandy soils, loams, chalk soils, and peaty soils. The details of the composition of these different types are discussed in Part II, Chapter 2.

Clay soils are referred to by the farmer as heavy soils, and are characterized by their power of retaining moisture and by the difficulties encountered in their cultivation. During winter, clay soils become wet and sodden, and spring cultivations have to be delayed until the soil has dried to a state in which it can be worked. If there is a spring drought, there is a danger of the soil becoming too dry for the preparation of a seed bed. Clay soils cannot be used for arable farming except in an area with a low rainfall, and even under these conditions they are used mainly for autumn sown crops. The two important arable land crops associated with heavy land are wheat and beans, and heavy land is sometimes described as "wheat and bean" land. There is a considerable area of heavy land in East Anglia in the counties of Essex, Suffolk, Cambridgeshire, and Huntingdon on which wheat is the principal cash crop. The fall in the price of wheat during the past 50 years has resulted, in many cases, in land of this nature being put down to permanent pasture and used for dairying. But in an area with a rainfall of less than 25 inches a year, this type of land does not make good grassland, as it is too wet for winter grazing, and in summer it dries out and develops large cracks. Even with a higher rainfall, grassland on clay soils is not of first class quality and is used largely for dairying. There is a large area in the Midlands,

and another in Cheshire and North Shropshire, consisting of heavy land where the chief system of farming is dairying.

Light, sandy soils are noted for their ease of cultivation and for their free draining properties, but by comparison with heavy soils they are often of low fertility. The great disadvantage of these soils is the risk of summer droughts, and in areas with a low rainfall the lightest soils are more suited to forestry than to farming. In general, counties with a high proportion of the lighter types of soil are predominantly arable. The soil is light enough to allow sheep to be folded on the land in winter, and the cereal mostly associated with this type of soil is barley. Soils of this character are specially suited for market gardening, because they can be cultivated at almost any time of the year, and they warm up quickly in the spring and encourage the production of early crops for market. All the districts in England and Wales noted for market gardening have a light soil, and examples may be found in the counties of Bedfordshire, Worcestershire, Kent, and Hampshire, where market gardening has developed. In the parts of the country with a high rainfall, the lighter soils are used for arable farming, and in these conditions there is no fear of crops suffering from summer drought.

Between the extremes of clay soils and sandy soils are the soils described as loams. These soils are light enough to promote free drainage and to allow of cultivations, yet are heavy enough to retain sufficient moisture for the benefit of crops in summer. When soils of this type are devoted to arable farming, a wide range of crops can be grown on them ; and when put down to permanent grass the heavier loams produce grassland of the highest quality, which is used for the summer fattening of beef cattle.

Chalk soils are light in character and free draining, and farming on them consists of arable crops at the lower levels, and the keeping of sheep on the higher chalk downs. These soils have been derived from chalk, which is a form of calcium carbonate, and normally they have a high calcium content, which makes them very suitable for barley and for the leguminous fodder crops such as lucerne, sainfoin, trefoil, and vetches. There is a large area of chalk soils in England stretching from Dorset and Hampshire in the south, through Berkshire, Hertfordshire, and Cambridgeshire into Norfolk, and appearing again in a part of Lincolnshire and the East Riding of Yorkshire. Sheep and barley are the two products most associated with this type of soil.

There are two types of peaty soils in England and Wales, which are roughly classified as black fens and peats. The black fen soils are found around the Wash, mainly in the Isle of Ely and the Holland division of Lincolnshire, and a reference to the map in

Fig. 6 shows that these two counties have more than three-quarters of their land devoted to arable farming. The soils are rich and fertile and are used mainly for cash crops such as potatoes, sugar beet, and wheat. The peat soils found in other parts of the country are often associated with moorland conditions, and, unless they are drained and limed, are usually classified as rough grazings.

Market Conditions

The third factor that influences the type of farming in a district is that of market conditions. The development of industry in certain areas of England and Wales has resulted in the growth of towns with large urban populations, who require food. This has created a special market for farm produce, and around all large cities the type of farming is affected by the nearness of a large consuming centre. Although the soil and climate may not be ideally suited for it, market gardening, fruit and flower growing, and milk production are carried on around most large cities, the great advantage being the ability of the grower to get perishable produce to the market in a very short time. The effect of nearness to market on farming is not so pronounced to-day as it was formerly, because modern improvements in transport have enabled farmers at greater distances from the consuming centres to send their produce to the market in good condition. It is now possible, by road transport, to collect produce from quite remote farms and to get it to the urban consumer. The railways have introduced large glass-lined tanks for the transport of milk, and, in the season, special trains are run from most fruit- and vegetable-growing districts to get the produce quickly to the market.

Variety of Farm Practice

From the account that has been given, it will be seen that many factors have an effect on the type of farming, and that conditions in England and Wales give rise to a great variety of farm practice. It is almost impossible to isolate the effects of climate, soil, and market, for it is a combination of these factors that determines the best policy for a particular farm. The one variable factor is the condition of markets and prices, and every farmer should make sure that at any one time he is making the best use of his farm under existing circumstances while being ready to adapt his policy to a change in circumstances.

CHAPTER 4

DISTRIBUTION OF FARM CROPS

THE diagram given in Fig. 1 (page 8) shows that, in 1939, 30 per cent of the land in England and Wales was used for arable farming, and the figures given in Table 1 (page 7) show that the area devoted to arable crops in 1939 was a little under 9 million acres. The arable acreage in England and Wales has been steadily declining for the past seventy years. Statistics relating to agriculture were first collected in 1866, and in 1870 the area of arable land was nearly 15 million acres. The decrease in the cultivated area has been accompanied by an increase in the area of land under permanent grass, the figures in 1870 being about

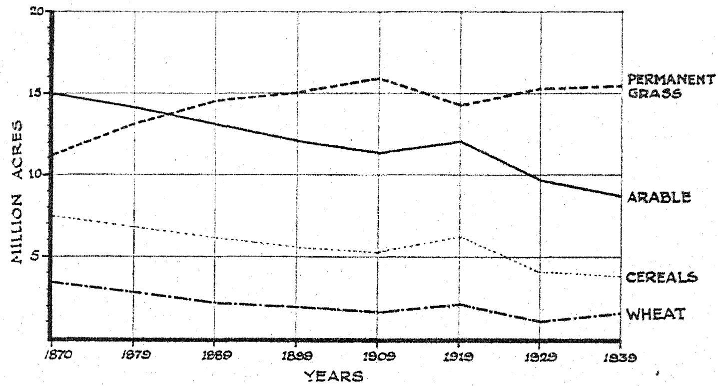


FIG. 7. CHANGES IN THE CROPPING OF ENGLAND AND WALES, 1870-1939

11 million acres, and in 1939 a little under 16 million acres. During the same period, there has been a considerable acreage of land lost to farming because of the growth of towns and the taking of farm land for building purposes. Other land has been abandoned as farm land and classified as rough grazings. These changes in the character of farming are illustrated in the graphs given in Fig. 7. The decline in the arable acreage of the country was temporarily arrested during the war of 1914-18, when agriculture was subject to Government control. With the end of the ploughing-up campaign, however, the fall continued, and it is of interest to note that the arable acreage in 1939 represents the same rate of decline that might have been expected had there been no interruption due to the war.

Arable Acreages

The following table gives the area devoted to the principal farm crops in England and Wales in 1939.

TABLE 5

ACREAGE OF THE PRINCIPAL FARM CROPS IN ENGLAND AND WALES IN 1939

CROP	ACREAGE IN 1939	ACREAGE IN 19
Wheat	1,683,000	
Barley	910,000	
Oats	1,358,000	
Potatoes	454,000	
Sugar Beet	337,000	
Turnips and Swedes	396,000	
Mangolds	210,000	
Rape	53,000	
Cabbage, Kale, etc.	94,000	
Rotation Grasses	2,072,000	

In 1939 the area devoted to wheat, barley, and oats was approximately 4 million acres, whereas in 1870 the acreage under these three crops was more than 7 million. The decrease in arable farming over the past 70 years has been mainly associated with the decline in cereal growing, and has been due to the steady fall in the world prices of cereals during the same period. This has placed the British farmer at a serious disadvantage with the producers of cereals in America, Canada, Argentina, and Australia, whence the British Isles have received large imports of these products. The decline in cereal acreage has been almost entirely confined to wheat and barley, whilst the acreage of oats has remained more or less constant. Of the other crops, there has been a decline in the acreage of turnips, swedes, and mangolds, and an increase in that of potatoes. The sugar beet crop was not grown in this country in 1870 but in 1939 more than 300,000 acres were devoted to this crop. Sugar beet now occupies a part of the acreage that was previously used for the growing of fodder roots for stock. The acreage under rotation grasses, or seeds leys, has also declined, but the proportion of arable land devoted to this crop has increased. Thus in 1870, the proportion was approximately 20 per cent, whereas in 1939 it was a little more than 23 per cent.

DISTRIBUTION OF CASH CROPS

Of the crops given in Table 5, the four important farm cash crops are wheat, barley, potatoes, and sugar beet. Cash crops in 1938-9 represented 14·5 per cent of the agricultural output, and a money value of nearly £32,000,000 to the British farmer. The following table shows how this figure is divided between the cereals, potatoes, and other crops.

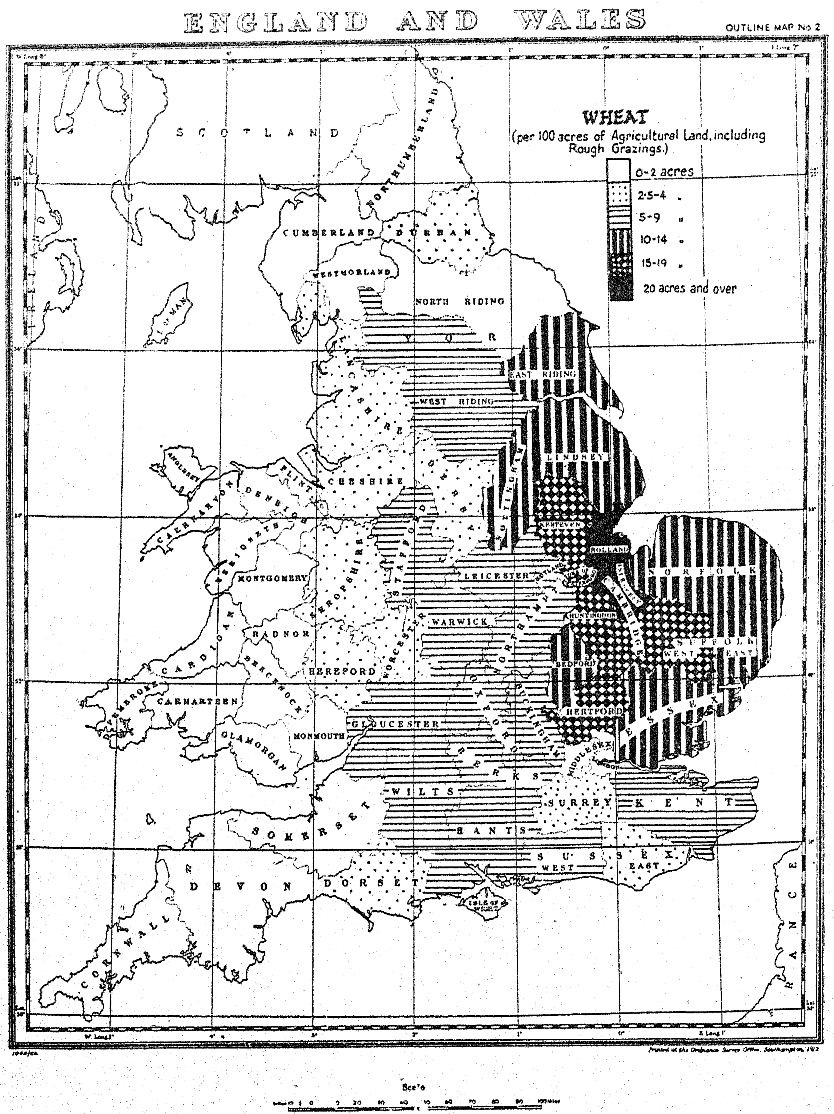
TABLE 6

OUTPUT FROM THE SALE OF CROPS IN ENGLAND AND WALES IN 1938-9

CROP	VALUE 1938/9	PER CENT	VALUE 19 /	PER CENT
Wheat	£4,660,000	14·7	£	
Barley	£3,980,000	12·5	£	
Other grain crops ..	£1,890,000	6·0	£	
Potatoes	£11,370,000	35·5	£	
Sugar Beet	£4,380,000	14·0	£	
Other crops	£5,520,000	17·3	£	
Total	£31,800,000	100.0	£	

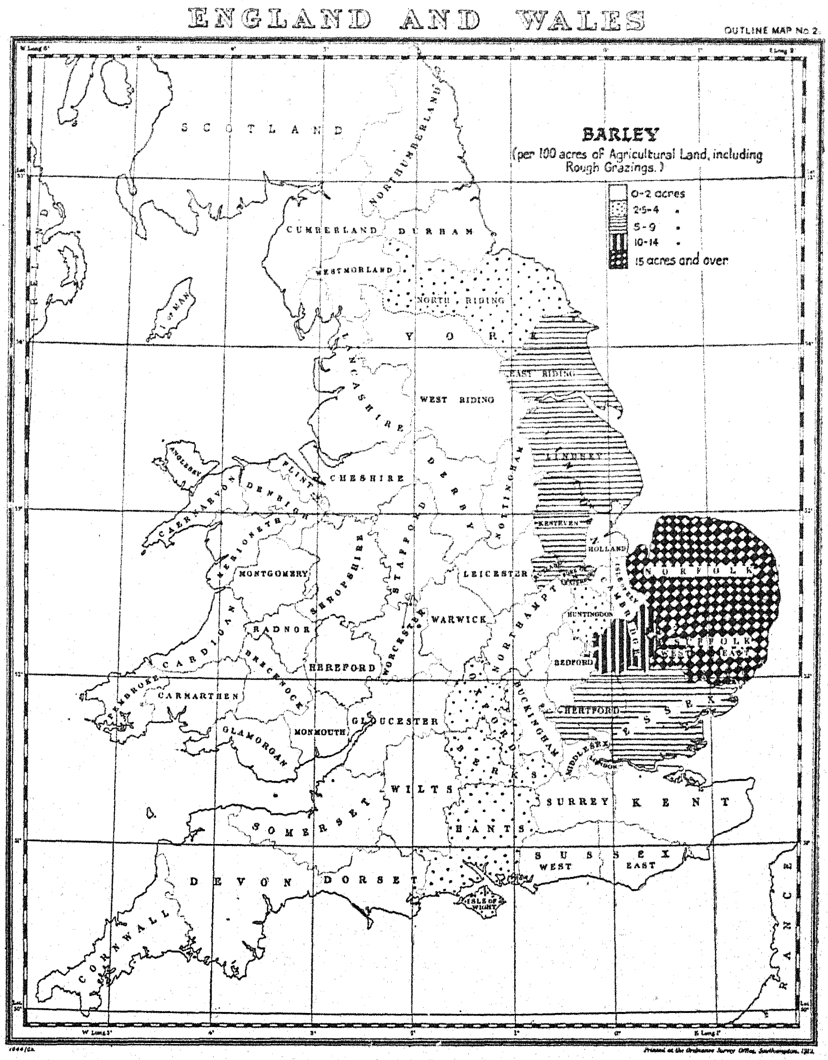
Note.—In addition to these values, £8,820,000 was paid to wheat growers under the Wheat Act, and £2,070,000 as a subsidy for barley and oats.

WHEAT. It will be seen that, in spite of the decline in the total acreage of wheat, it still occupied the greatest acreage of the cereal crops. The drop in price has resulted in the concentration of wheat growing in those parts of the country that are most suited to its cultivation, and the map given in Fig. 8 shows the distribution of the wheat acreage in England and Wales in 1939. The greatest concentration of wheat growing was in the flat area of fen soils surrounding the Wash, and in the Isle of Ely and the Holland division of Lincolnshire wheat occupied more than 25 per cent of the total agricultural land. The acreage devoted to wheat decreased outwards from this point of concentration, and if the map in Fig. 8 is compared with the maps in Figs. 2 and 5, giving rainfall and temperature, it will be seen that wheat was grown mainly in the areas of lowest rainfall and highest summer temperatures. It will be noted that little wheat was grown in counties outside the line denoting a July temperature of 60°F. Within the area of wheat cultivation, the heavier soils are used for wheat because of their ability to retain moisture during the summer when temperatures are high. The greatest concentration is,



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 8. THE ACREAGE OF WHEAT IN 1939 RELATED TO TOTAL ACREAGE OF CROPS AND GRASS (INCLUDING ROUGH GRAZINGS)



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 9. THE ACREAGE OF BARLEY IN 1939 RELATED TO TOTAL ACREAGE OF CROPS AND GRASS (INCLUDING ROUGH GRAZINGS)

however, in the two counties whose soils are mostly of the black fen type, which, because they are low lying, are surrounded by open dykes or ditches in which for most of the year there is water within a reasonable distance of the surface. As a crop, wheat can be grown on a wide variety of soils, but it prefers clays, heavy loam, and fen soils, mainly because of moisture.

Two features of wheat growing in England are worthy of mention. Firstly, in the matter of quality, the varieties of wheat grown in this country are not very suitable for bread making, and are used chiefly for biscuit manufacture and for poultry food. Newer varieties are available that produce a flour of a quality as good as that of imported wheats, but these varieties require the best conditions for their successful cultivation. Secondly, the yield of wheat under English conditions averages about 18 cwt. an acre, or 32 bushels, with yields in the better years rising to a figure of 30 cwt., or more than 50 bushels an acre. This is a high level of yield compared with many of the wheat producing countries, few of which exceed an average yield of 20 bushels an acre.

BARLEY. The conditions needed for successful barley growing are similar to those needed for wheat, though it prefers a lighter type of soil, and if grown on the black fen soils does not produce a high quality grain for malting. The map given in Fig. 9 shows the distribution of the acreage of barley in England and Wales in 1939. The highest proportion of barley was grown in Norfolk, where the percentage was 18 per cent of the total agricultural land, whereas the highest concentration of wheat was more than 25 per cent. It will be noted that the growing of barley was almost entirely confined to the areas of low rainfall, and as a crop it is even less tolerant of wet conditions than wheat. The yields of barley are less than those of wheat, the average for the country being about 16 cwt. The best quality barley is used to make malt for the brewing of beer, and a good malting sample commands a much higher price than barley of feeding quality. As a food for livestock, barley forms a large proportion of the rations for pigs, and is also used for cattle.

POTATOES. This is a crop grown almost entirely for human consumption and one in which the British Isles are nearly self-supporting, apart from the importation of small quantities of new potatoes early in the season. The demand for potatoes is highest in industrial areas, and as potatoes are a bulky crop relative to their value, and transport costs may therefore be unduly high, a large acreage of potatoes is grown for local consumption. Thus in the counties of Durham, Stafford, the three Ridings of Yorkshire, Warwickshire, Worcestershire, and Kent, about 2 per cent

of the total land in 1939 was devoted to potatoes for the neighbouring consuming centres. There is a remarkable concentration of potato growing in two areas, one in the Isle of Ely and the Holland division of Lincolnshire, and the other in Cheshire and Lancashire. The first district is in the Fens, and in Holland in 1939 more than 24 per cent of the total agricultural land was devoted to potatoes and the figure for the Isle of Ely was a little more than 18 per cent. These two counties alone grew nearly 100,000 acres of potatoes in 1939, representing over 21 per cent of the total acreage for England and Wales. The potatoes from this district are sent principally to the London market. In Cheshire and Lancashire, there is an area of light friable soil very suitable for potato growing: in 1939, 5 per cent of the total agricultural land in Cheshire was under potatoes, and 4 per cent in Lancashire. In these counties a large proportion of the total land is under grass, and if the acreage of potatoes is related to arable land only, the figures were 11 per cent for Cheshire, and nearly 18 per cent for Lancashire. The potatoes grown in this area find their market in the big industrial towns of Lancashire. The yield of potatoes fluctuates considerably from year to year, and is affected chiefly by climatic conditions. The average yield for the country over a period of ten years is about 6 tons an acre.

Sugar Beet. Although sugar beet has been grown in Europe as a source of sugar since about 1800, it was not until 1924 that the crop became an important one in British farming. In that year, the Government granted a subsidy to assist the establishment of sugar beet growing in this country. It was hoped that by 1934 the industry would have been able to continue without further Government assistance, but the subsidy has had to be continued.

The development of sugar beet as an important crop in British agriculture came at a time when arable farming was steadily declining. It provided farmers, particularly in the eastern counties, with a cash crop to replace roots grown as a cleaning crop and cashed indirectly by the feeding of sheep. It also assisted in the retention on the land of many workers who would otherwise have left the industry through lack of employment. The cost to the country of establishing the crop has been criticized, but during the war of 1939-45 the domestic sugar ration was supplied from home-grown sugar beet and this may be put forward as some justification for the money spent on the crop.

As a crop, sugar beet grows best in light and deep soils and in an area with a low autumn rainfall so that the harvesting is not hindered. The establishment of the crop has been influenced mainly by these considerations, and sugar beet factories have been built in the areas most suitable for it. The greatest acreage is

grown in the eastern counties, and there are other, smaller concentrations in Yorkshire, Nottinghamshire, and Worcestershire. The following table illustrates the distribution of the crop in 1939 :—

TABLE 7

DISTRIBUTION OF SUGAR BEET IN ENGLAND AND WALES, 1939

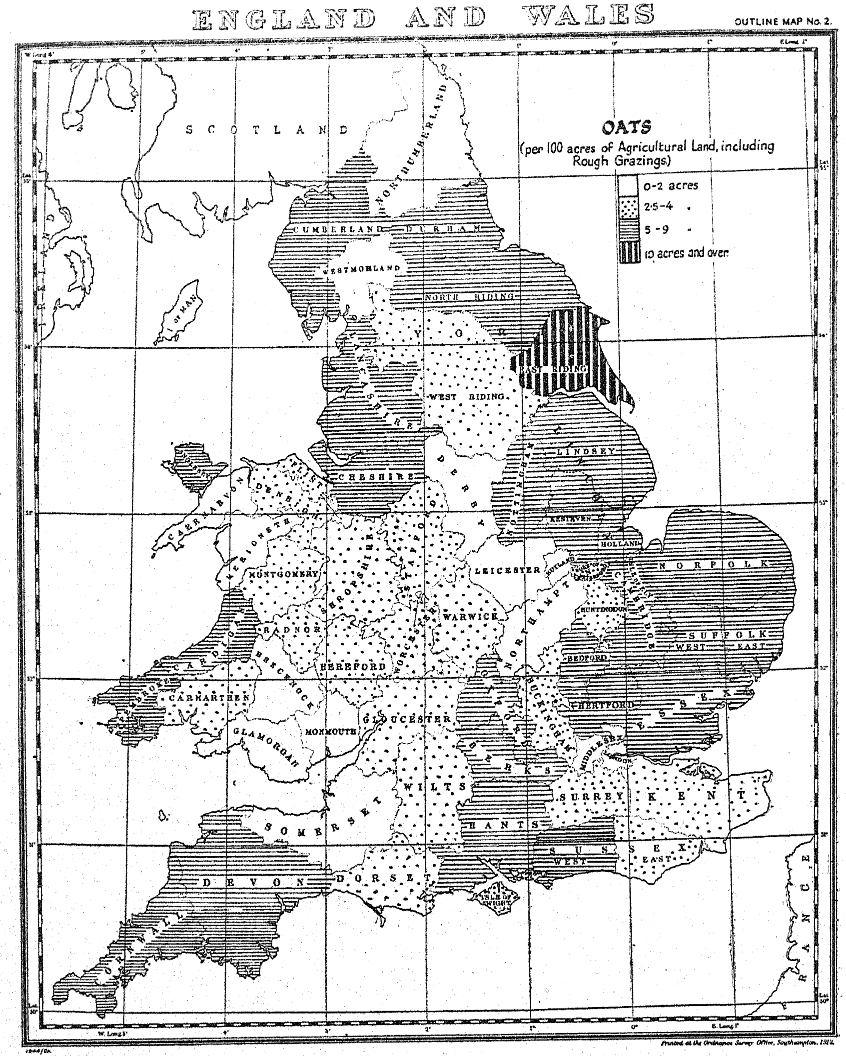
COUNTY	NO. OF FACTORIES	ACREAGE 1939	% OF TOTAL	ACREAGE 19	% OF TOTAL
Eastern Counties :—					
Cambridge	1	12,551	3·7		
Isle of Ely		27,524	8·1		
Essex	1	12,820	3·8		
Huntingdon	–	10,439	3·0		
Lincoln, Holland ..	1	12,570	3·7		
Lincoln, Kesteven ..	1	16,608	5·0		
Lincoln, Lindsey ..	1	25,349	7·6		
Norfolk	3	89,391	26.5		
Soke of Peterboro' ..	1	2,945	0·9		
Suffolk, East.. ..	1	23,368	6·9		
Suffolk, West ..	1	24,098	7·2		
	11	**257,663**	**76·4**		
Yorkshire, E. Riding ..	–	11,240	3·3		
Yorkshire, N. Riding ..	1	7,809	2·3		
Yorkshire, W. Riding ..	1	8,109	2·4		
	2	**27,158**	**8·0**		
Nottingham	2	7,882	2·3		
Salop	1	13,545	4·0		
Stafford..	–	3,974	1·2		
Hereford	–	3,231	1·0		
Worcester	1	2,351	0·7		
	4	**30,983**	**9·2**		
Other Counties ..	–	21,256	6·4		
Total	–	337,060	100·0		

These figures show that nearly three-quarters of the acreage of sugar beet was grown in the Eastern Counties, and that Norfolk grew more than a quarter of the total acreage for the whole country. The great importance of the crop in the Eastern Counties can be appreciated by relating the acreage of sugar beet to the acreage of arable land. In this group of counties, the 247,224 acres of sugar beet represented 8·5 per cent of the total arable land, and the acreage in the Isle of Ely represented 16 per cent, in the Soke of Peterborough 13 per cent, in Norfolk 12·5 per cent, and in West Suffolk 11 per cent. The comparable figure for the area in the West Midlands was 4·5 per cent of the arable land devoted to sugar beet, and for Yorkshire the figure was 2·7 per cent. As with the potato crop, sugar beet is bulky in relation to its value, and unless there is a factory within reasonable access of the grower, the costs of transport become excessive. In addition to being an important cash crop, sugar beet provides a supply of tops that can be fed to livestock ; and after the manufacture of sugar, the residue, known as sugar beet pulp, is also an excellent food for stock. The crop gives an average yield of 10 tons an acre of roots, and 6 or 7 tons of tops, and the roots give an average of 15 per cent of sugar.

Distribution of Feeding Crops

Oats. Of the three cereal crops in England and Wales, oats are far more widely grown than wheat or barley. The acreage under oats in 1939 was 1,368,000, and the map given in Fig. 10 shows the distribution of the crop. It will be seen that there is no great concentration of oat growing as there is with wheat and barley, and only one county, the East Riding of Yorkshire, had 10 per cent of its total agricultural land under oats. The explanation of this wide distribution is twofold. Firstly, oats as a crop can grow and ripen under cool, moist conditions and replace wheat and barley as the cereal crop in the west and north. Secondly, oats are grown primarily for home consumption, and every farmer endeavours to grow sufficient oats for the feeding of his horses. Several of the eastern counties had more than 5 per cent of the total agricultural land growing oats, because of the greater number of horses in the areas of arable farming. Oats are also used extensively for feeding to dairy cattle, and the counties of Cheshire and Lancashire had 7 per cent of their land under oats, for these are areas with a high concentration of dairy stock.

In England and Wales, about 18 per cent of the oats grown are sold, but only a small proportion is used for human consumption. The most important demands for oats are for the feeding of non-agricultural horses, including hunters, race-horses, and horses used



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 10. THE ACREAGE OF OATS IN 1939 RELATED TO TOTAL ACREAGE OF CROPS AND GRASS (INCLUDING ROUGH GRAZINGS)

for haulage in towns, and for the feeding of poultry. The average yield of oats is 18 cwt. an acre, and, by comparison with wheat and barley, the straw is a valuable fodder for livestock.

BEANS AND PEAS. In some districts these crops are grown as food for livestock, but their distribution shows a concentration in the Eastern Counties. The area of beans for stock feeding in 1939 was 133,000 acres, and of this acreage, nearly one-third was grown in the counties of Essex and East and West Suffolk. In these counties there is an area of heavy clay land where beans are used as the cleaning crop, with wheat as the important cash crop. The acreage of peas for stock feeding was 37,000, and they were grown almost exclusively in the counties on the east coast, from Kent in the south to the East Riding of Yorkshire. A light soil is more suitable for the growing of peas.

FODDER 'ROOTS'. A number of different crops grown for feeding to stock are included under this heading, the most important being turnips and swedes, mangolds, rape, kale, and cabbage. Since 1914 there has been a considerable reduction in the acreage devoted to fodder roots, mainly because of increasing labour costs, which became uneconomic for crops with only an indirect cash value, and because ample supplies of cheap feeding-stuffs were imported from overseas. The total acreage under all kinds of fodder roots in England and Wales in 1914 was more than 1½ million acres, and the corresponding figure for 1939 was ¾ million acres, which shows a decline of 50 per cent.

Of the individual crops, the greatest decrease was in the acreage of turnips and swedes, which in 1914 occupied more than 1 million acres, and in 1939 occupied 396,000 acres, a decrease of 62 per cent. Turnips were the first root crop introduced into British farming, and their cultivation began in Norfolk about 200 years ago. They were of great value as a new source of winter feed for stock, and their cultivation gradually spread throughout the country. Turnips and swedes prefer a cool, moist climate, and they have proved most suitable for the west and north of England. In 1914, the growing of these crops was fairly widespread, and large acreages were grown in the south and east of England, in the counties of Dorset, Hampshire, the Lindsey and Kesteven divisions of Lincolnshire, Norfolk, and East and West Suffolk, where they were fed to arable-land sheep. The biggest decline in the acreage of turnips and swedes has been in these counties, and has been accompanied by decreases of between 40 and 50 per cent in the number of sheep. There has also been a decline in the north of England, where turnips are used for both cattle and sheep, and in the counties of Cumberland, Durham, Northumberland, Westmorland, and Yorkshire the decline in acreage between 1914 and

1939 was 43 per cent. In 1914, these five counties grew about one-quarter of the acreage for the whole country, whereas in 1939 the proportion had risen to 37 per cent. The acreage of turnips and swedes in these five counties represents 10 per cent of the arable land, a figure similar to the proportion of sugar beet to the arable land in the eastern counties.

The acreage under mangolds declined from 432,000 in 1914 to 210,000 in 1939. Mangolds do not grow well in cool and moist climates, but flourish on the heavier soils in the eastern counties. By contrast with turnips and swedes, mangolds must be lifted and clamped because they are susceptible to frost damage. The only types of fodder crops that have shown an increase in acreage from 1914 to 1939 are cabbages and kale, and an acreage of 52,000 in 1914 had increased to 94,000 in 1939. The crop mainly responsible for this increase was kale, which gives a high yield of dry matter an acre, has a higher protein content than mangolds, and is widely grown as a fodder for dairy cattle.

The effect of imported feeding-stuffs on the practice of growing fodder roots as a food for stock in peace-time can be seen by the increased acreages grown under war-time conditions when imported feeding-stuffs are in short supply. The total acreage under fodder roots in 1944 showed an increase of 33 per cent over the acreage for 1939, and, in the case of kale, the acreage was more than doubled.

Rotation Grasses. Included under this heading are the various mixtures of grasses and clovers grown as a part of the rotation of crops on arable land. They represent a little less than one-quarter of the total arable land for England and Wales, but the practice of growing seeds or temporary leys differs from one part of the country to another. In the arable areas of the east, the ley is usually sown for one year only; whilst in the west and north, longer leys, lasting from four to seven years, are more common. The leys are used for the feeding of stock, and about one-third of the acreage is grazed and two-thirds used for hay. The area under rotation grasses in 1939 was a little over 2 million acres, and this represented the greatest acreage under a single crop on arable land. Temporary grass of this nature is generally superior to all but the very best grassland in both yield of hay and quantity of grazing, and there are many enthusiastic advocates of a great extension of ley farming in place of the permanent grass that occupies a large proportion of the land in England and Wales.

Distribution of Specialized Cash Crops

The figures given in Table 8 on page 35 show that in 1938-9, an output valued at £33,070,000 was obtained from the production

of fruit, vegetables, and flowers. This figure was divided among the different types of crops according to the following table.

TABLE 8

OUTPUT DERIVED FROM THE PRODUCTION OF FRUIT, VEGETABLES AND FLOWERS IN ENGLAND AND WALES IN 1938-39

TYPE OF CROP	VALUE 1938/9	PER CENT	VALUE 19 /	PER CENT
Fruit	£5,640,000	17·0		
Vegetables ..	£18,650,000	56·4		
Greenhouse Produce and Flowers	£8,780,000	26·6		
Total ..	£33,070,000	100·0		

The fruit crops grown in England and Wales are classified as small fruit, which includes strawberries, raspberries, gooseberries and currants, and orchard fruit, chiefly apples and plums. The area devoted to small fruit declined from an acreage of 77,358 in 1914 to 47,200 in 1939, but showed a similar distribution in both years. In 1914, the counties of the Isle of Ely, Kent, Norfolk, and Worcester grew 53 per cent of the total acreage of small fruit, and in 1939 the percentage in these four counties was 56. The decline in the acreage of small fruit has been most marked in the case of strawberries and raspberries. One effect of the war has been a further reduction, and the area of small fruit in 1944 had declined to 31,000 acres. The probable reasons for the fall in acreage are the high costs of labour, and the speculative nature of these crops, their yields being very susceptible to weather conditions. It is also associated with a loss of vigour in the plants when the crop has been grown continuously in the same areas for many years, the land becoming what is known as "strawberry sick." The growing of these crops calls for specialized knowledge, and there has been little development in new districts where farmers have no experience of the crops.

The acreage of land planted with orchards has shown a slight increase between 1914 and 1939, the acreages being 243,000 and 254,000 respectively. Of the orchards, more than a half of the acreage is planted with apple trees. The county with the greatest area under orchards is Kent, which in 1939 had nearly 70,000 acres, representing nearly 10 per cent of the total area of the county. Worcestershire had about 23,000 acres under orchards in 1939, representing 6 per cent of its total area. Other acreages exceeding 20,000 were grown in Devon, Somerset, and Hereford-

shire, where cider apples are the predominating type of fruit.

In 1939, the acreage devoted to the growing of vegetables was approximately a quarter of a million, but the total acreage for 1914 was not recorded. A comparison of the acreages of individual vegetable crops for the two years shows a striking increase, carrots having increased from 11,000 to 16,000 acres, cauliflowers and broccoli from 8,000 to 19,000, and brussels sprouts from 11,500 to 38,000 acres. In 1914, the growing of vegetables was concentrated in a small number of counties, whereas in 1939 it had become much more widespread. This is shown in Table 9, and it will be noted that the greatest proportional increases in acreages have been in the arable land counties in the east, as a result of the general arable farmer devoting a part of his land to a vegetable cash crop. The other increases in acreage have been in the counties near the larger industrial areas, as in Lancashire, Yorkshire, and Warwickshire. Most of the vegetables grown in the eastern counties are destined for the London markets. One of the most important vegetable crops is cabbage, which in 1939 occupied more than 44,000 acres. Figures for this crop in 1914 are not available, but since 1930 there had been an increase of 10,000 acres under this crop, which gives an indication of the way in which the acreage was expanding in the years before the war.

A more specialized form of production is that of vegetables and flowers under glass, and, as in this case soil, temperature, and moisture can be controlled, the glasshouse crops are invariably grown as near as possible to the consuming centre. There is a great concentration of glasshouse culture in the Lea Valley to the north of London, where it is calculated that about 1,000 acres of land are covered with glasshouses, which are producing principally tomatoes, cucumbers, and flowers for the London market. Another district with a considerable glasshouse acreage is in Sussex behind Worthing and Brighton, from which produce is also sent to London.

The money output from fruit, vegetables, and flowers was, in 1938-9, more than that obtained from the sale of general farm crops. Only thirteen years before, in 1925, the output from general farm crops was more than twice that of these specialized cash crops. The increasing importance of these crops is reflected in these figures, and it is not unlikely that, in the future, even greater attention will be paid to fruit and vegetables because of the part they should play in raising the nutritional standards of this country. It has been convincingly shown during the war that more vegetables can be grown in England and Wales, and the acreage in 1944 showed an increase of nearly 64 per cent over that of 1939.

TABLE 9

ACREAGES OF CERTAIN VEGETABLE CROPS IN 1914 AND 1939

COUNTY	ACREAGE 1914	ACREAGE 1939	ACREAGE 19
Brussels Sprouts.			
Bedfordshire	4,788	10,333	
Worcestershire	1,014	5,259	
Hertfordshire	326	2,345	
Gloucestershire	152	1,952	
Huntingdonshire	354	1,948	
Norfolk	82	1,940	
Cambridgeshire	369	1,810	
Warwickshire	120	1,371	
W. Suffolk	40	1,152	
Lancashire	148	1,054	
Carrots.			
Norfolk	210	2,534	
Yorkshire, E. Riding ..	1,045	2,429	
Isle of Ely	1,410	1,714	
Lindsey	1,875	1,663	
W. Suffolk	57	1,230	
Huntingdonshire	348	812	
Yorkshire, W. Riding ..	140	709	
Bedfordshire	1,083	215	
Broccoli and Cauliflower.			
Kent	1,194	3,906	
Cornwall	1,108	2,935	
Lancashire	455	1,295	
Yorkshire, W. Riding ..	602	1,022	
Holland	232	955	
Devonshire..	73	581	

Chapter 5

DISTRIBUTION OF FARM LIVESTOCK

THE pre-eminent position occupied by livestock in the farming of England and Wales has already been stressed, and the figures given in Table 10 below show that the output derived from livestock and livestock products in England and Wales in 1938-9 was £154,560,000. The table shows how the different forms of livestock contributed to this total.

TABLE 10

OUTPUT OF LIVESTOCK AND LIVESTOCK PRODUCTS IN ENGLAND AND WALES, 1938-9

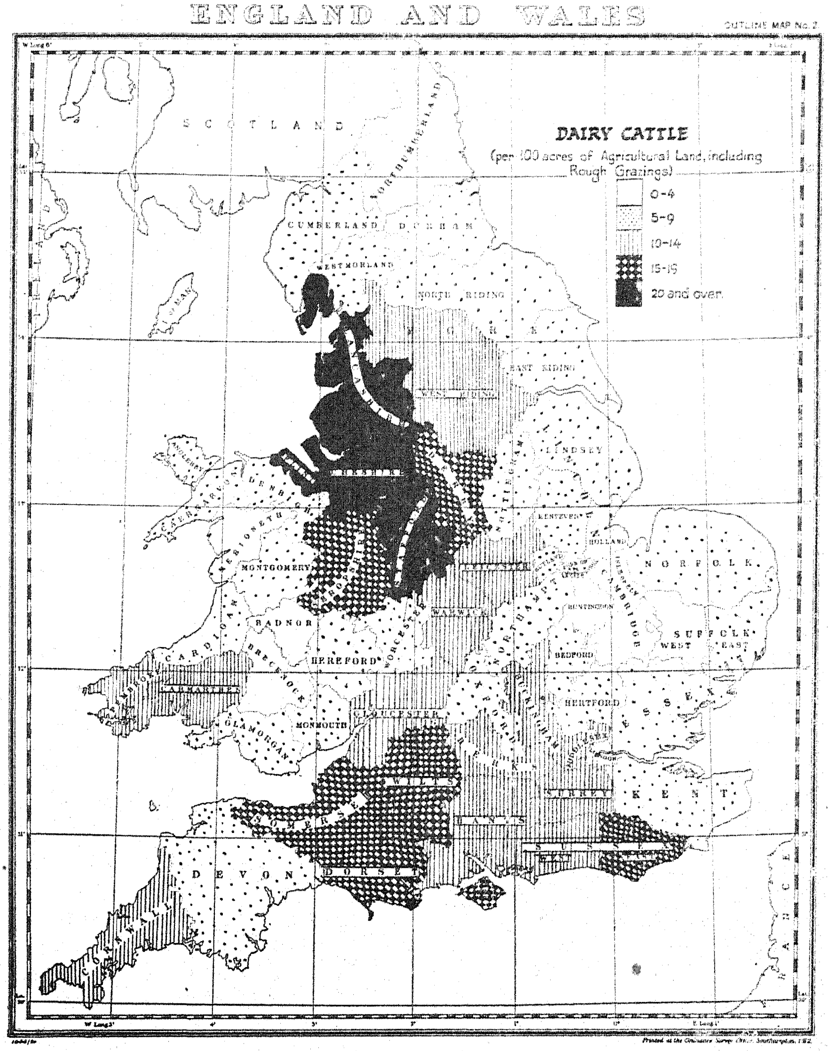
TYPE OF PRODUCT	VALUE 1938/9	PER CENT	VALUE 19 /	PER CENT
Milk and Dairy Produce..	£64,630,000	42	£	
Cattle and Calves ..	£27,760,000	18	£	
Sheep and Lambs ..	£14,250,000	9	£	
Wool	£1,990,000	1	£	
Pigs	£24,820,000	16	£	
Poultry and Eggs ..	£21,110,000	14	£	
Total	£154,560,000	100	£	

Note.—In addition to these values, a sum of £3,050,000 was paid as a subsidy on fat cattle.

Dairy Cattle

It can be seen from this Table that dairy cattle contributed 42 per cent of the livestock output. The dairy industry is the largest single branch of farming, and represents about 30 per cent of the total output of stock and crops. In 1939, the number of cows and heifers in calf and in milk was a little more than 3 million, an average of 10 dairy cows for every 100 acres of agricultural land. By comparison with 1914, the population of dairy cattle had increased by 25 per cent.

The map given in Fig. 11 shows the distribution of dairy cattle in England and Wales in 1939. The greatest concentration was in Cheshire, where there were 31 dairy cattle for every 100 acres,



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 11. NUMBERS OF DAIRY CATTLE IN 1939 RELATED TO TOTAL ACREAGE OF CROPS AND GRASS (INCLUDING ROUGH GRAZINGS)

and the three neighbouring counties of Flint, Lancashire, and Staffordshire all had a dairy cattle population of more than 20 for every 100 acres. The milk from this area is mainly sold to the industrial towns of Lancashire. The effect of consuming centres on milk production can be seen by the numbers of dairy cattle in the counties surrounding Birmingham, and in the West Riding of Yorkshire and the neighbouring county of Derby. London obtains a considerable amount of its milk requirements from the three western counties of Dorset, Somerset, and Wiltshire.

The increase in dairy production since 1914 was most marked in counties which were then primarily arable counties with sheep and fattening cattle as the main forms of livestock. In the counties of Berkshire, Norfolk, and East Suffolk the numbers of dairy cattle had increased by more than 50 per cent between 1914 and 1939, and Hampshire showed an increase of 44 per cent. This is a reflection of the profitability of dairying during the period by comparison with crop production and the fattening of cattle in yards during winter.

The distribution of dairy cattle did not coincide with the distribution of permanent grassland as given in Fig. 3. The needs of dairy cattle are better supplied by growing a part of their food on arable land, and grassland of the highest quality is not necessary because the grazing has to be supplemented by home-grown arable crops or by purchased feeding-stuffs.

In 1939, it was estimated that the average consumption of milk in England and Wales was less than half a pint a day for each person. The value of milk as a food has been greatly emphasized as a result of war-time conditions, and the demand has increased to such an extent that a system of rationing had to be introduced. For the future, it may be that the demand for milk will continue and that post-war consumption will increase, so that dairying may become an even more important branch of farming. An increase in the consumption of milk would be in accordance with modern standards of nutrition, and, as there are no imports of fresh milk, an extension of dairying would make the British farmer less subject to foreign competition.

Most of the milk produced in this country is sold for liquid consumption, but in the summer, when there is a surplus of milk not needed for this purpose, the milk is sent to factories for the making of cheese and dried and condensed milk. One important change in the milk industry is the decline in the making of butter and cheese on farms. This was the common practice years ago, especially on farms too remote for the sale of liquid milk. Modern developments in transport and the greater profitability of liquid milk are responsible for this decline.

Other Cattle

The figures for cattle, other than dairy cattle, in 1939 were made up as follows :—

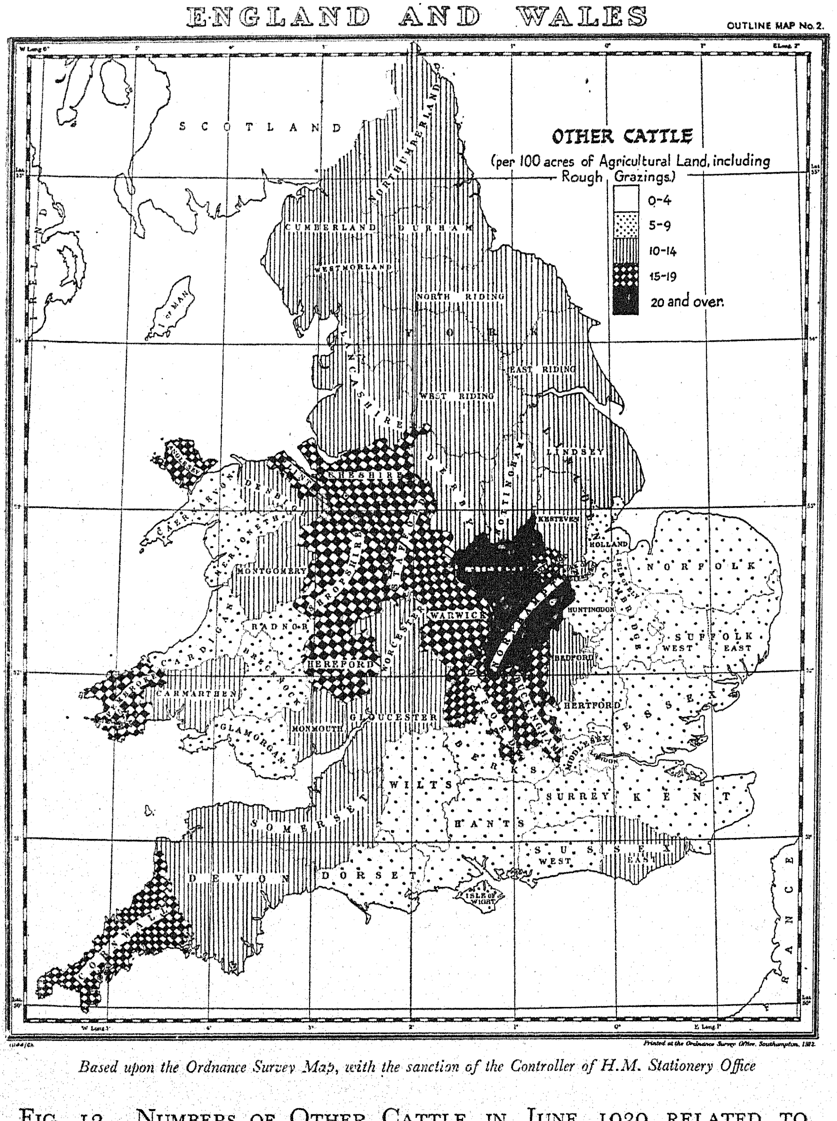
TABLE 11

CATTLE OTHER THAN DAIRY CATTLE

	1939	19
Under 1 year old	1,242,000	
1 year and under 2 years	1,346,000	
2 years and over	944,000	
Total	3,532,000	

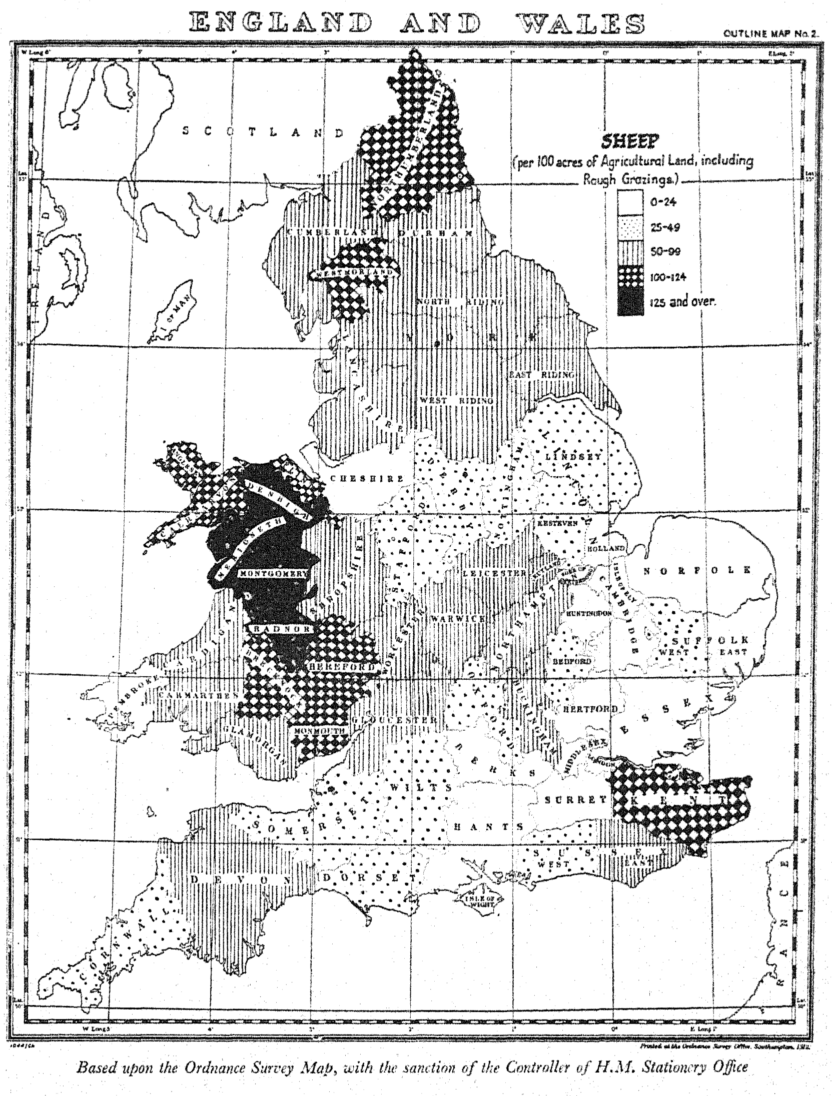
The map given in Fig. 12 shows the distribution of these cattle on 4th June, 1939. It will be seen that the area of greatest concentration was in Leicestershire and Northamptonshire, two counties noted for their excellent pastures, which are capable of producing fat cattle on grass alone. Other counties have smaller areas of these fattening pastures, often on flat land near the mouths of rivers and near the sea. In these two counties the number of cattle over two years of age greatly exceeded the numbers in the two lower age groups, and most of them had been brought into the county in the spring as store cattle and had probably spent the previous winter in yards on arable farms. In Northumberland and Westmorland, there were more cattle over two years old than under. Some of these were being fattened on grass and others being kept on poorer types of grassland as stores, to be fattened on turnips and cake in the following autumn.

The cattle in the younger age groups are more varied in character. In dairying districts, many of the younger cattle are reared as replacements for the dairy herd. In other districts where the grassland is not of the best quality, the rearing of store cattle is an important farm practice. Some of the calves are born on the farm, and others are surplus male calves from the dairy districts, which are bought and reared as store cattle, though they may not produce a good fattening animal. At the end of the summer many of these young stock are sold and spend the next winter in the yards of an arable farm, consuming roots and hay and making farmyard manure. The store cattle are mainly reared in the west of the country, and there is a steady movement of cattle from the west and north to the arable farms of the east and south. It will be noted that numbers of cattle in the arable counties were low in June, when the cattle yards were empty. The distribution of



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 12. NUMBERS OF OTHER CATTLE IN JUNE 1939 RELATED TO TOTAL ACREAGE OF CROPS AND GRASS (INCLUDING ROUGH GRAZINGS)



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 13. NUMBERS OF SHEEP IN 1939 RELATED TO TOTAL ACREAGE OF CROPS AND GRASS (INCLUDING ROUGH GRAZINGS)

cattle in December would be very different from that shown in the map in Fig. 12, but no figures of the numbers of cattle in December have been published from which this seasonal movement of cattle could be traced.

By comparison with 1914, the figures for other cattle show a slight increase in total, but not to the same extent as dairy cattle. In 1914 the figures for other cattle were 58 per cent of the total, and in 1939 the proportion had fallen to 54 per cent.

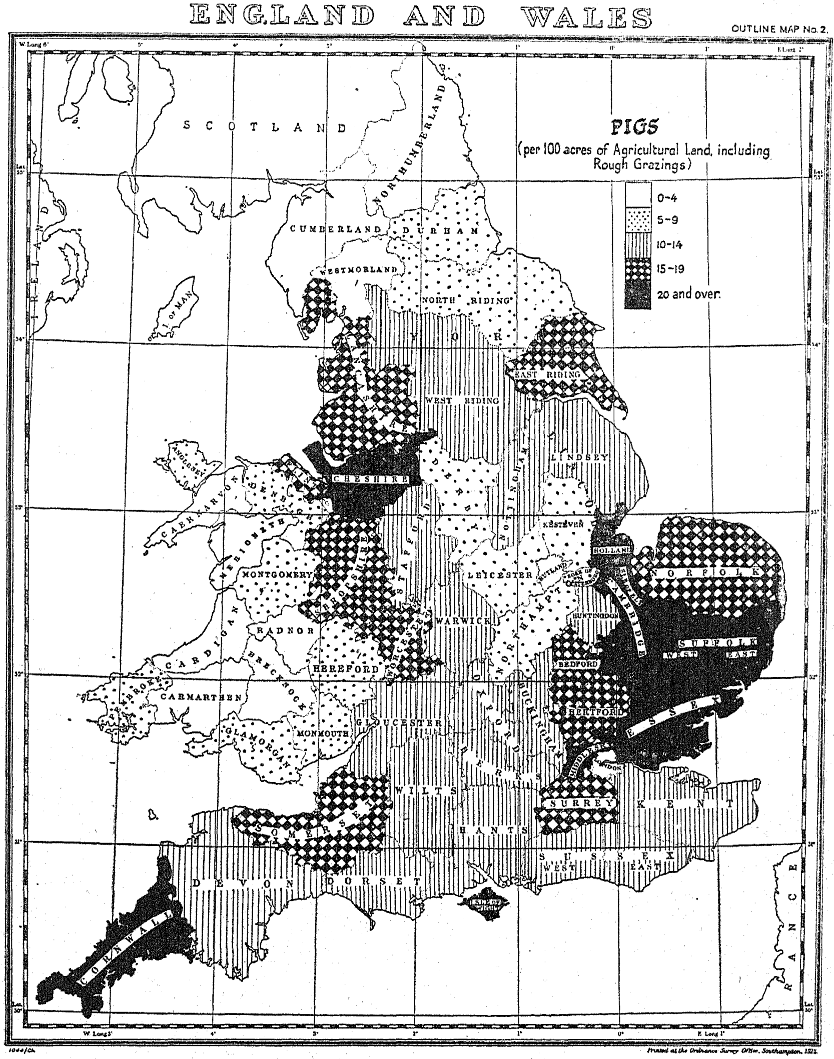
Sheep

The total number of sheep in England and Wales in 1939 was nearly 18 million, and the map given in Fig. 13 shows their distribution. As would be expected, the greatest concentration of sheep was in the Welsh counties of Denbigh, Merioneth, and Montgomery, where the keeping of sheep on the hills is the only possible system of farming. The numbers of sheep were also high in the other counties with a considerable proportion of rough grazings, particularly in the other Welsh counties, and in Cumberland, Northumberland, and Westmorland. The sheep kept in these districts are hardy mountain sheep adapted to the rough and exposed conditions in which they live. In Devon, Hereford, Kent, Somerset, and Shropshire large numbers of sheep were kept, and in every case a native breed has been developed to suit local conditions.

Other counties with a comparatively high sheep population were those associated with the summer fattening of cattle, where sheep are put on the grassland with the cattle to ensure even grazing. These are mainly sheep of grassland breeds, and crosses between mountain and grassland breeds. The number of arable sheep had declined during the past 20 years and no great concentrations were to be found in the arable counties. The total number of sheep in England and Wales increased by about $\frac{3}{4}$ million between 1914 and 1939.

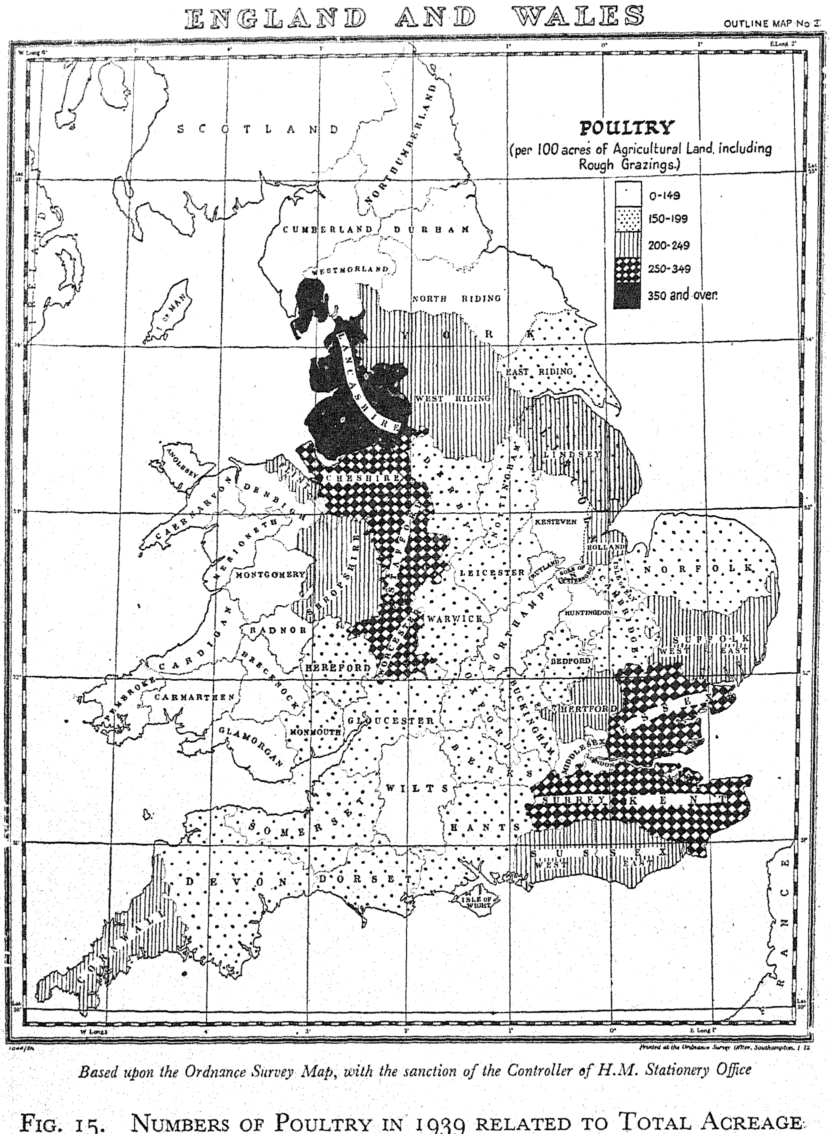
Pigs

The map given in Fig. 14 shows the distribution of pigs in England and Wales in 1939, when the total numbers were about $3\frac{1}{2}$ million. The areas where the largest numbers of pigs are kept are associated either with dairying or with the growing of potatoes or barley. In these cases, pigs are often used to consume the by-products arising from some other enterprise. In Cornwall, skimmed milk, after the making of cream, and in Cheshire, whey from the making of cheese, are frequently disposed of as food for pigs. In Holland and the Isle of Ely, pigs are used to consume the small and waste potatoes, and in Suffolk they utilize the barley that is not of good malting quality.



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 14. NUMBERS OF PIGS IN 1939 RELATED TO TOTAL ACREAGE OF CROPS AND GRASS (INCLUDING ROUGH GRAZINGS)



Based upon the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office

FIG. 15. NUMBERS OF POULTRY IN 1939 RELATED TO TOTAL ACREAGE OF CROPS AND GRASS (INCLUDING ROUGH GRAZINGS)

Poultry

The distribution of poultry in 1939 is shown in the map in Fig. 15. Lancashire had a poultry population of 753 for every 100 acres of agricultural land, a figure more than twice as great as the next highest population of 312 in Cheshire. Staffordshire and Worcestershire in the Midlands, and Essex, Surrey, and Sussex in the south-east had more than 250 birds for every 100 acres, but apart from these seven counties poultry were fairly evenly distributed throughout the country. As shown in Table 10, the value of sales from poultry and eggs amounted in 1938-9 to over 21 million pounds. Of this figure, 5 millions were for poultry and 16 millions for eggs. It will be seen by reference to Table 6 on page 25 that the sales of poultry produce were practically equal to the total receipts from all grain crops, which, including the payments received as subsidy and under the Wheat Act, amounted to £21,420,000.

Horses

Horses are kept on farms primarily as a source of power and not as a form of livestock to give produce for sale. With the advent of the tractor, the numbers of horses are declining. In 1914, there were 1,400,000 horses in England and Wales, and by 1939 the number had fallen to 846,000, a decrease of 40 per cent. Some farmers derive an additional source of income from the breeding and sale of horses for work in towns.

The Effect of War on Livestock Policy

The outbreak of war in 1939 brought with it the control of British agriculture by the Government. The critical factor in deciding upon a war-time policy was the lack of shipping space, which compelled a reduction in the imports of human food and animal feeding-stuffs. The Government initiated a campaign for the ploughing-up of permanent grassland, and the additional arable land had to be used to increase the production of crops for direct human consumption, and of crops for the feeding of livestock. It was obvious that, with this new policy, the pre-war livestock population could not be maintained, and a system of priorities had to be introduced.

For the sake of the health of the nation, first priority was given to milk production; and where possible, it was necessary to produce from the land a large proportion of the food requirements of dairy cattle. Such supplies of imported feeding-stuffs as were available were rationed, and first preference was given to the needs of dairy cattle. As a result of this policy, the numbers of dairy cattle in England and Wales increased between 1939 and

1944 by approximately 12 per cent, whilst the increase in the total cattle population was only 2 per cent.

Apart from cattle, all other forms of livestock showed a substantial decrease in numbers between 1939 and 1944. The greatest reductions were in pigs and poultry. These two classes of stock were very dependent before the war on imported cereal foods, which under conditions of war would have been competing directly with imported cereals for human consumption. Rations for pigs and poultry were issued on the basis of one-sixth of pre-war numbers, but the decrease in numbers was not so severe because it was possible to use some home-grown feeding-stuffs for them, supplemented, in the case of pigs, by an extensive use of swill. The number of pigs declined by 58 per cent and of poultry by 43 per cent.

Sheep showed a reduction of nearly 30 per cent, due to the lower acreage of grassland and the need to use the unploughed grass for dairy cattle. Horses were reduced by 16 per cent, the consequent loss of power being more than replaced by the greater use of tractors.

The effect of this change in livestock policy is reflected in the acreages of farm crops in 1939 and 1944. The total arable area was increased by 63 per cent, representing more than 5½ million acres. The following list of percentage increases in the acreage of certain crops between 1939 and 1944 shows the emphasis that was placed on crops for direct human consumption and for the feeding of livestock.

Crops for Direct Human Consumption.

Wheat	82%
Barley	89%
Potatoes	116%
Sugar Beet	25%
Vegetables	64%

Crops for Feeding to Livestock

Oats	64%
Beans	107%
Mangolds	43%
Rape	185%
Cabbage and Kale	110%
Temporary Grasses	43%

PART II
THE PRINCIPLES OF CROP PRODUCTION

CHAPTER I
PLANT GROWTH

THE basis of all forms of agriculture is the growth of plants, and their utilization as food for man or for animals. Farming can only be carried on successfully in conditions in which plants will grow. Even a simple type of farming, such as the keeping of sheep on a hillside, depends upon the fact that certain plants, in this case grasses, are able to grow in this environment. Many systems of farming are concerned not with the plants that would flourish under natural conditions, but with crops that demand a considerable amount of time and attention from a farmer, who must provide them with conditions under which they will grow and yield an economic return. A thorough understanding of the principles and practice of crop husbandry must begin with a knowledge of how a plant grows, and of the conditions in which a plant will grow successfully.

Plants of importance to agriculture are of many different forms, but they all consist essentially of three main parts. Below ground is the rooting system, which serves as an anchorage to attach the plant firmly to the soil, and which is able to absorb water, and water solutions of plant nutrients, from the soil. Above ground are the stems and leaves, which are the green parts of the plant. The stems are, in most cases, rigid and capable of keeping the plant erect, and the leaves are arranged on the stems in a manner that exposes them to sunlight, from which they absorb energy for the manufacture of materials for plant growth. The third essential structure in a plant is the flower, which contains the parts associated with reproduction and which is ultimately responsible for seed formation.

The rooting system remains in darkness below the surface of the soil and is usually white in colour. In many rooting systems, there is a central root, sometimes known as the tap root, from which a number of side roots develop as branches, and the side roots end in a large number of fine rootlets. When examined under a lens, the end of a rootlet is seen to consist of a cap at the very tip, and behind the tip are numerous fine root hairs, which absorb water and water solutions of plant nutrients from the soil. The rootlets and side roots contain a series of hollow vessels, which connect with those of the central root, and through these the substances absorbed by the root hairs pass and in time reach the base

of the stem. Another series of vessels in the stem is available for the passage of these materials to the leaves and flowers. There are other vessels present in the leaves and stems through which the plant foods manufactured in the leaves are transferred to the roots or to the flowers. In one sense, a living plant may be described as a self-contained system of transport, which moves water and nutrients taken in from the soil and plant foods from the leaves and distributes these substances throughout the plant as they are needed for growth or storage. Provision is also made for the disposal of surplus water out into the surrounding atmosphere by way of openings in the leaves.

Annual, Biennial, and Perennial Plants

In the course of its growth, a plant passes through a definite cycle consisting of three separate stages : germination, the development of vegetative parts, and flowering, with the final production of seed. Some plants complete the cycle of growth within one season, and are referred to as annuals. The cereals and pulse crops, which are grown on the farm for the purpose of utilizing their seeds as food, are annuals. Some common farm weeds have an even shorter cycle of growth. Shepherd's purse, for example, goes through several growing cycles in one season, and plants of this nature are known as ephemerals, a word meaning short-lived. Many weeds of a troublesome character found on farms are annuals, and unless destroyed before flowering they produce a large number of seeds, which infest the soil for another season.

Many plants need two years to complete their cycle of growth. The first season of growth is devoted to the growth of vegetative parts and the building up of a reserve of plant foods which is available in the second year of growth for the production of flowers and seeds. Plants in this group are known as biennials, and all of them create a reserve of food for the second year, though there are many variations in the type of storage organs. Some of the common garden flowers, such as sweet-williams and Canterbury bells, produce in the first season a large number of leaves, which remain as a flat rosette during the winter and send up a flowering shoot the following spring. A number of garden vegetables, such as carrots, parsnips, and turnips, and many farm root crops, including mangolds and sugar beet, store a reserve of food in the "root" or in some modification of it, and produce a flowering stem in the following year. With some farm root crops, there may be a number of plants that produce flowers and seeds in their first season of growth. These are said to have "bolted" and are useless to the farmer, as there is no reserve of food to be used for human or animal consumption. Crops of the cabbage family are

also biennials. Broccoli and cauliflowers in the first season of growth produce a modified form of flowering head known as the curd, whilst cabbages produce a solid heart of leaves, and brussels sprouts a number of solid buds attached to the main stem. These are the parts used by man as a source of food. From the examples that have been given, the economic importance of biennial crops will be realized. There are not many biennial weeds on arable land, because the reserve of food stored for a second year is destroyed by the cultivations carried out on the land, and they have little chance of survival.

There is a third group of plants known as perennials. Many of these produce flowers and seeds every year, but the plants themselves survive and gradually increase in size. Some perennials are described as herbaceous, and the leaves and stems die down at the end of the growing season. A familiar example of a herbaceous perennial is the Michaelmas daisy, which is found in most gardens, and there are a large number of similar herbaceous flowering plants. On the farm, many grasses and other fodder crops, such as lucerne and sainfoin, are herbaceous perennials. The potato is a herbaceous perennial and the tubers are a form of underground stem. If the plant were left undisturbed in the ground, it would continue to spread by fresh growth from all its tubers; but in farm and garden practice, the tubers are lifted each year and a new crop is obtained by planting a number of selected tubers the next year. Other forms of perennial plants are described as shrubby, and some are trees, with a number of wooden branches, which increase in size from year to year. The stems do not die down in winter but, apart from the evergreen plants, most trees and shrubs lose their leaves. Fruit trees and bushes are examples of this type of perennial plant with an economic importance, and all the plants connected with forestry are of this character. There are many perennial weeds found on agricultural land, and, because of their underground storage of food reserves, they are difficult to eradicate. Familiar examples of perennial weeds are coltsfoot, couch grass, docks, and bindweed.

Germination

The first stage of plant growth is the germination of the seed. A seed consists of a small embryo plant with rudimentary roots and leaves, and a supply of plant food which can be made available to the young plant when growth begins. This will feed the young plant during the first stage of its life before it has been able to establish an independent existence. Seeds mature and ripen before they are harvested, and, provided they are kept dry and not at too high a temperature, they remain alive but dormant for

quite a long time. Some seeds, especially if they have a high content of oil, remain alive for a number of years and grow into plants as soon as conditions are suitable. The seeds of charlock may remain buried in the soil for many years whilst a field is under grass, and start into growth when the field is ploughed again. But with most seeds, the number that remain alive gradually decreases with storage, and the percentage of living seeds in a sample of old seed is often quite low.

Three conditions are necessary before seeds will germinate. The first is a supply of water, which is absorbed by the seed and which causes it to swell. Next, the temperature must be high enough to encourage growth to begin, and to allow the reserve of food in the seed to turn into a soluble form for absorption by the newly developing plant. Lastly, the germinating seed and the growing embryo need a supply of air from which they obtain the oxygen needed to transform the food reserve into the energy needed for growth. No seed will germinate unless it is provided with water, warmth, and air, and the absence of any one of the three will prevent growth from starting. This has an important bearing on farming practice. In the winter, the soil contains an ample supply of moisture, but the temperature is too low to permit of germination. At the height of summer, the temperature is suitable for germination, but there is every likelihood of an absence of sufficient moisture. Thus the two main seasons for the sowing of farm crops are the autumn and spring. In the autumn, the soil is still warm after the summer sunshine, and rain would normally have fallen to provide a supply of water. By the end of November, in most districts in the British Isles, the temperature will have fallen below the level at which germination is possible. As the soil begins to warm up in the spring, conditions once more become favourable for germination and farmers resume the sowing of their crops.

As germination proceeds, a fine delicate root begins to penetrate into the soil and a small green shoot appears above ground. At this early stage, the plant is unable to absorb any nutrients from the soil, and is entirely dependent on the food which is stored in the seed. Germination may be said to be completed when the roots have grown sufficiently to be able to absorb water and nutrients from the soil, and when the leaves have opened above ground and have started the important function of manufacturing materials to support further growth. When this stage has been reached the plant may be considered as having an independent existence, and the next stages of growth take place.

Quality of seed, particularly in respect of its purity and its power of germination, has an important influence on the eventual

crop. The buying and selling of seed are matters of great commercial importance to farmers, and the conditions under which these transactions may take place have been laid down by regulations made under the Seeds Act. At the time of selling seed for sowing, the seller is required to give certain information mainly concerned with the percentage of purity and of germination. This information is obtainable from a seed testing station.

The question of the purity of seed is, with most farm crops, a matter of the sample being properly cleaned to remove the seeds of other plants, particularly weeds, and such impurities as bits of chaff, broken seeds, or particles of soil. Most samples offered for sale possess a high percentage of purity, and there is little danger to be feared from impurities other than weed seeds. With some of the smaller farm seeds, like the grasses and clovers, the sample may contain seeds of injurious weeds such as docks and Yorkshire fog, and if these are present to more than a very small extent, the seed may not be offered for sale. There are special conditions for the sale of clover seed, which may contain the seeds of a particularly dangerous parasitic plant called clover dodder, which grows as a parasite attached to the clover plant and would seriously damage a clover crop if present in any quantity. A sample containing more than one seed of dodder in one ounce of clover seed cannot be offered for sale.

Samples of seed should be tested to ascertain the percentage of seeds capable of germination. These tests can be carried out by a seed testing station and are done on groups of 100 seeds, which are placed on a damp cloth or paper, put into an incubator, and kept for a certain number of days at a constant temperature. At the end of the test, the seeds that have germinated are counted and this gives the percentage of germination. Farmers who use their own home-grown seed should always have a germination count made. Tests for purity and germination of seed for sale, or for a farmer's own use, can be carried out at the Official Seed Testing Station at Cambridge* for a modest fee.

There are several reasons why a sample of seed may have a low percentage of germination. The sample may be old so that many of the seeds have lost their vigour, or the seed may have been harvested under unfavourable conditions. The plants may not have been fully matured when cut, or the crop may have been damaged by rain when standing in the shock, so that some of the grains sprouted. The loss of germination may be due to the seed having been stored in conditions that were too hot or too damp, either of

* Further details can be obtained from the Chief Officer, Official Seed Testing Station, Huntingdon Road, Cambridge.

which would cause the seed to deteriorate. It is obvious that good seed contributes to the production of a good crop, and farmers often fail to give sufficient attention to the choice of seed.

There are a number of theories and opinions held by many farmers as to the value of a change of seed as opposed to using home-grown seed, but there is little experimental evidence to support them. One important factor in the production of seed is a dry climate, which leads to better ripening, and to better harvesting conditions. It is important to realize that what has been said here with regard to change of seed does not refer to the problem of "seed" potatoes. From a botanical standpoint, "seed" potatoes are not seeds but tubers which are used for the reproduction of the plant, and change of seed is essential in potato growing.

Development and Growth of the Plant

The second stage of plant growth, following germination and the establishment of the young seedlings, is the development of the vegetative parts, which comprise the rooting system in the soil and the stems and leaves above the surface. The materials necessary for growth are obtained partly by absorption through the root hairs in the soil, and partly from the materials made in the green leaves. The conditions necessary for growth to take place in a satisfactory manner are complex in character and include the soil and its constituents, which are to some extent under the control of the farmer, and the presence above ground of air and light, matters over which the farmer has little or no control.

The most important of the factors affecting plant growth is the supply of water. A growing plant contains at least 80 per cent of water, and it is the water contained in the soft parts of the plant, such as the leaves, which keeps them in a firm and fresh condition. A shortage of water leads almost at once to a plant wilting and becoming soft and limp. Water is also the medium by which the roots absorb plant nutrients. The solution of salts to be absorbed is very weak ; and when the plant has extracted the nutrients from the solution, there remains a far greater quantity of water than is needed to keep the tissues in their shape. The excess water has to be disposed of, and it passes out to the atmosphere through small openings found mainly on the underside of the leaves.

The process of the movement of water from the leaves to the air is known as transpiration. A growing crop removes very large quantities of water from the soil in the course of a season. Under the climatic conditions that prevail in the British Isles, it has been estimated that for every 1 lb. of dry matter produced by a crop, the plants have absorbed and transpired from 250 to 300 lb. of water. Thus an acre of wheat, which produces on an average

about one ton of grain and one ton of straw, removes about 500 tons of water from the soil. This is the equivalent of 5 inches of rainfall, and most of this water is needed at times when least rainfall is expected. Lack of water may become a limiting factor in plant growth, and in a dry climate care must be taken to avoid unnecessary losses of water from the soil such as might be caused by too many cultivations. In some parts of the world, the annual rainfall is insufficient to support a crop of wheat every year and the practice of taking a crop every other year has had to be adopted.

Another factor essential to plant growth is a supply of air from which the plant can obtain oxygen. As with most living organisms, a plant cannot exist without oxygen, which is taken in and used in the breaking down of carbohydrates to provide the energy required for life. This breakdown results in the formation in the plant of carbon dioxide, which passes out to the atmosphere. The process is known as respiration, and may be simply defined as the process of breathing in oxygen and breathing out carbon dioxide. In animals, respiration is done only through the lungs, but in plants all parts are capable of absorbing oxygen and giving off carbon dioxide. Thus it is not correct to describe the leaves as the lungs of a plant, for respiration is going on with the roots below ground. If there is a shortage of air in the soil, the roots do not obtain sufficient oxygen and plant growth is stunted, and in extreme cases the plants will die. The most likely cause of a shortage of air in the soil is the presence of too much water, so that the soil is waterlogged, and good drainage in the soil is essential for plant growth. The importance of water for plant growth has already been stressed, but the amount of water available in the soil will affect the supply of air to the roots. There is a limited amount of space between the soil particles and excessive water in the soil means a deficiency of soil air. Under the conditions of farming in England and Wales, most farm crops are capable of using as much water as they can get, provided the soil is not so wet as to cause a shortage of air.

It has been pointed out that seeds will not germinate if the temperature is too low, and warmth is also needed for plant growth. A plant will not necessarily die at a low temperature, but little or no growth will take place if the temperature is below 41°F., which is 9 degrees above freezing-point. For the crops grown in the British Isles, the best temperature for growth is about 80°F., which represents a fairly warm summer's day. If the temperature rises much above this figure, the plant matures early, so that the period of growth is cut short, which results in a reduction of yield.

Supply of Plant Nutrients

In addition to the factors of water, air, and warmth, the plant must be provided with a supply of nutrients to support its growth. These come in part from the soil, and there are a number of chemical elements that are essential for growth and must be in a form in which the roots can absorb them. The most important of these elements are nitrogen, phosphorus, and potassium. They are not used by the plant as single chemical elements, but are combined with other elements to form substances which dissolve in water. Thus, nitrogen as a single element is a gas, but for plant nutrition it is combined with oxygen to form a nitrate, and the nitrate is combined with another chemical, for example calcium, to form a salt which dissolves in water. It is of the greatest importance to realize that plant nutrients are more readily absorbed by the roots when they are soluble in water. It may be possible, by chemical analysis, to find sufficient quantities of nitrogen, phosphorus, or potassium in a soil to meet the needs of a plant, but if they are not soluble in water, they do not contribute so readily to the growth of the plant. When in this form, plant foods are described as being not available, and it is only available plant foods that contribute to growth.

Each of the three elements that have been mentioned affects different parts of a plant during its period of growth. Nitrogen is mainly associated with the development of leaves and stems, and the presence of sufficient nitrogen is shown by green healthy leaves. An almost certain indication that a plant is suffering from a lack of nitrogen is given when its leaves develop a pale and yellow appearance. If a crop is given excessive nitrogen, the leaves and stems become soft and sappy and show an unusually dark green colour. With a cereal crop, excess nitrogen may weaken the straw to such an extent that it is unable to support the ears of grain, and the crop is laid flat on the ground, which adds considerably to the difficulties of harvesting.

The phosphorus needed for plant growth is associated more especially with the development of the rooting system, and it also has an effect on flowering and seed formation by encouraging earlier ripening. In some respects, phosphorus counteracts the effects of too much nitrogen by providing the strong growing leaves and stems with a good root system, and prevents the excessive growth of leaves and stems from delaying the ripening of the crop.

The effect of potassium on plant growth is not as clearly defined as with nitrogen and phosphorus. It is needed by the plant as a whole and helps to keep it in a healthy condition by making it less liable to attack by disease. It has a more direct effect on the leaves, and causes them to retain a healthy green colour which makes

them more efficient in the manufacture of materials for plant growth.

In addition to nitrogen, phosphorus and potassium, there are many other elements essential to plant growth, but they are not required in the same quantity. They include calcium, sulphur, magnesium, iron, manganese and others, but they are required in very small amounts and most soils contain sufficient quantities. In some cases, the element may not be present in an available form, which causes the plants to display certain abnormal characteristics, and may even lead to the development of disease. Apart from calcium, the quantities of these nutrients needed by plants are so very small that they are sometimes referred to as trace elements. An example of the effect of a trace element on a crop is that of boron, the absence of which causes sugar beet to develop a disease known as "heart rot." This disease can be cured by applying boron to the soil.

Although the plant absorbs a large number of substances from the soil, the greatest increase in its dry matter does not come from the soil but from the materials manufactured in the leaves. Some 300 years ago, a classic experiment was carried out which helped to prove the source from which a plant derived its bulk. A branch of a willow tree was planted in a pot containing 20 lb. of soil and was allowed to grow for five years. The surface of the soil was covered to prevent the addition of dust or any other substance, and only rain water was added to it. The willow branch weighed 5 lb. at the beginning of the experiment, and at the end of the five years it had increased to 164 lb. But when the soil was weighed at the end of the experiment, it had decreased by only two ounces. This proved that the plant had been able to obtain most of its food from a source other than the soil in which it was growing. It is now known that the increase in weight was derived from the materials made in the leaves.

The basis of the manufacture of materials for plant growth in the leaves is the combination of water and carbon dioxide to form simple sugars, which are then changed into the more complicated substance known as starch. Chemists express this by an equation which states that six parts of water (H_2O) are combined with six parts of carbon dioxide (CO_2) to form one part of sugar ($C_6H_{12}O_6$) and there are six parts of oxygen (O_2) left over. The equation is written thus: $6\ H_2O + 6\ CO_2 = C_6H_{12}O_6 + 6\ O_2$. The water needed for this process is taken up from the soil and transferred to the leaves, and the carbon dioxide is absorbed from the air. The oxygen which is left after the formation of sugar passes out from the leaves to the air. The combination is carried on in specially constructed cells in the leaves, but it takes place only in

the presence of sunlight or relatively strong daylight, and plants are manufacturing starch continuously during the hours of daylight. By night, the process stops, and the food which has accumulated during the day is transferred to other parts of the plant.

In order to bring about this manufacture of carbohydrate from water and carbon dioxide, some form of energy is required and this is absorbed from the sun's rays by the green colouring matter found in the leaves. When a plant is grown in the dark, its leaves do not develop a green colour, and are incapable of making sugars and starch until they have been exposed to light for some time and have turned green. Some plants have variegated leaves, and tests at the end of a sunny day prove that there has been no manufacture of starch in the colourless part of the leaf. The process is known as photosynthesis, a word made up from "photo," a Greek word for light, and "synthesis," which means building up. This process of building up by light is ultimately dependent upon the green colouring matter in the leaves, which is known as chlorophyll.

It will be appreciated that photosynthesis leads to the release of oxygen and is therefore the reverse of the process of respiration, which results in the breathing out of carbon dioxide. The plant continues to respire by day and night, but during the day it gives off the surplus oxygen that is not used for the purposes of breathing. When photosynthesis ceases at night, the plant continues to breathe and releases carbon dioxide.

During the period of vegetative growth, the plant absorbs nutrients from the soil and makes compounds containing carbon, hydrogen, and oxygen in its leaves. From these two sources, the plant obtains the materials necessary for the development of its different parts and for its increase in size, which is termed growth. At this stage in its life cycle, a plant is at least 80 per cent water, and the dry matter is partly in the form of carbohydrates, and partly in the form of substances containing nitrogen, of which the most important are proteins. The main structures of the plant, such as the fibres and cell walls, are formed from carbohydrates. It has been pointed out that biennial plants take two seasons to complete the cycle of growth, and by the end of the first season the period of vegetative development is completed, the plant having created for itself a reserve of food materials to provide for flowering and seed production the following season. The biennial crops grown on the farm are harvested at the end of their first season, when they contain the largest reserve of food, which is then used for the feeding of animals or for direct human consumption.

Flowering and Production of Seed

Annual plants complete the period of vegetative development early in the growing-season, and enter upon the final stage. This consists of the production of a flowering stem, and in due time the emergence of a flower. With many plants, the flowers are readily distinguished by their brilliant colourings, but the essential part of a flower is not its highly coloured petals. The seeds develop in a structure called an ovary, which is usually found inside the base of the flower, and has attached to it a style with a sticky end known as a stigma. The flower is provided with a number of stamens, which produce the pollen needed to fertilize the ovule and promote the formation of seed. At the time of pollination, a grain of pollen becomes attached to the stigma, where it germinates and grows down to the ovary. Some plants make use of the pollen from the stamens of their own flowers, and are described as being self-fertile. Other flowers are only fertilized successfully by pollen from the flowers of another plant of the same species. The chief agents for the transfer of pollen are wind and insects, in particular bees, which in their search for honey, collect grains of pollen on their bodies and deposit them on the stigmas of other flowers which they visit. The bright colours of flowers are mainly an attraction to insects for the purposes of pollination, whilst wind pollinated plants, such as the cereals and sugar beet, do not develop highly coloured flowers.

Once the flower has been pollinated and fertilized, the plant provides the newly formed seeds with a reserve of food materials, which will be needed when they themselves germinate. Practically all the food materials contained in the plant are transferred to the seeds. As this transfer nears completion, the leaves and stems gradually lose their green colour, and develop the brown and yellow colours associated with ripening. When the process is complete, the plant itself dies, and the seeds lose their moisture and become hard. They are then in a condition in which they remain dormant and can be stored. It is at this point that the cereals and pulse crops, which are grown for their seed, are harvested and threshed. Most of the seed, or grain, is used as foodstuffs, though a small proportion may be retained for sowing the following year.

Effect of Farming Practice on Plant Growth

It is now possible to summarize the conditions necessary for plant growth. At all stages, the plant requires air for respiration, water for transpiration, and warmth. Once germination is completed, the plant must be provided with certain nutrients which it absorbs through its roots, and its leaves must have access to air

and light to enable the manufacture of starch to take place. As it ripens, the plant needs ample warmth and sunshine so that it matures and becomes fit for harvesting.

The extent to which a farmer can influence the conditions of plant growth varies, but he can exercise a greater effect on the soil than on the conditions above the ground. Air, moisture, sunlight and warmth are primarily matters of weather conditions, over which the farmer has no control. In respect of air and sunlight, the farmer can assist plant growth by giving the plants ample room, by not sowing the seed too thickly, and by thinning the root crops sufficiently. He can prevent any overcrowding of the plants by the destruction of weeds which compete with the crop for air and light above ground, and for the water and nutrients in the soil. The cultivations of the soil have a very important effect on plant growth. They must be carried out to ensure an adequate supply of soil air, and to prevent unnecessary loss of moisture, though in some soils it may be necessary to remove excess water by means of drainage. Cultivations also increase the depth of soil through which the roots can grow to obtain plant nutrients. If, for any reason, the soil is deficient in the elements essential to plant growth, the crop suffers, but by the use of manures, these deficiencies can be made good.

The farm practices followed for the growing of crops, or crop husbandry, are ultimately an attempt to provide plants with the best conditions for growth. The cultivations carried out on the soil, the fertilizers that are applied, the system of drainage that is adopted, and the steps taken to destroy weeds are all directed to providing conditions in which crops grow satisfactorily and give an economic yield. Finally, some measure of control over plant growth can be exercised by choosing the most suitable variety for the soil and climatic conditions of the farm, and by the use of seed of high quality, which must be sown at the most suitable time for germination.

Chapter 2

THE COMPOSITION OF SOILS

THE soil is the surface layer of the earth, which is used in farming for the growing of plants. By contrast with the stock, implements, and buildings that are needed for farming, the soil is fixed and immovable and cannot be exchanged or rebuilt. If for reason of neglect, or bad farming, a soil loses its capacity to grow satisfactory crops, much time and effort are needed to bring it back into successful cultivation. The soil of a country should be regarded as its most important natural resource, and if there is no fertile soil, there can be no agriculture, and without some form of agriculture there can be no prosperity.

Although farming is dependent on soil, there are great variations between one soil and another, the differences being mainly in texture which is associated with the size of the soil particles. Soils vary in their fertility and productivity, and two soils that are similar in appearance may differ in their capacity to grow crops. To understand the character of a soil, it is necessary to know the factors that affect its texture and govern its fertility. From the farmer's point of view, the texture of a soil influences its cultivation, but texture alone cannot support plant growth. For this, the soil must provide the plant with the nutrients it requires. The extent to which a farmer can affect the inherent composition of a soil is limited, but much can be done to preserve the soil constituents in a satisfactory state of tilth and to maintain and raise the level of fertility. This aspect of the soil will be discussed in a later chapter.

The Formation of Soil

Basically, a soil consists of two main parts, one being mineral, or inorganic, in character, and the other organic. The mineral part has come from the breaking down of the rocks of the earth. The process of soil formation from the weathering of rock may be seen at the face of a quarry, or in a railway cutting. At the surface there is a layer of soil in which plants are growing. This may extend downwards for six inches to a foot and is darker in colour than the layer immediately below it. This second layer is known as the subsoil, and is partly broken down but contains a large number of stones. Still lower, the subsoil changes to solid rock. The change from top soil to the subsoil is also evident when trenches are being dug for drains. Some subsoils are light and sandy in character, others, especially under a clay soil, consist of

raw clay which may be blue or brown in colour. The weathering of rock into soil has taken many thousands of years, and the process began by the gradual breaking down of small pieces of rock until they were fine enough to allow certain hardy plants to grow. As these plants died year by year, the organic matter left behind was incorporated with the mineral matter, and in time other plants grew and the process has continued until a soil, as found to-day, has developed.

Some soils have been formed from the parent rock material found underneath them, and are known as sedentary soils. If such a soil is of a sandy nature, then the rock below it will give a sandy material when crushed or broken down. In other cases, the surface soil is very different in texture from the soil which would have developed from the underlying rock. This is evidence that the soil as found to-day has been formed from rock material brought from elsewhere many thousands of years ago. Many soils have been formed from the material carried along by rivers, and others from material deposited by glaciers. It is important to study the subsoil as well as the soil at the surface. A sandy soil with a sandy subsoil, under farming conditions, behaves very differently from a sandy soil with a subsoil of clay, though the two soils may be similar in appearance at the surface. The different layers from the top soil downwards are known as the soil profile, and this is always studied when surveys of the soils of a district are made.

Mineral Content of a Soil

The mineral portion of a soil, apart from stones, consists of a large number of particles of different sizes which are divided into four main groups known as coarse sand, fine sand, silt, and clay. Soil chemists have devised methods by which the different soil particles can be separated on the basis of their size. Coarse sand is the group with the largest particles and is similar in texture and particle size to demarara or coarse brown sugar, whilst fine sand consists of particles which give it the appearance of white castor sugar. Silt is smaller still and might be compared to cocoa, whilst clay is the smallest of all the particles and resembles finely ground flour when dry, and plasticine when wet. When a soil is examined, it will be noted that there is a tendency for the different particles to join together to form crumbs or granules of soil, and under field conditions, some of the soil is in the form of clods. Any mineral particles larger than coarse sand are referred to as stones. Some soils are very stony, whilst others have only a small percentage, but stones cannot yield any plant nutrient, though they may be of importance in the cultivation of a soil. A small percentage of stones helps to prevent a clay soil from becoming

too sticky, and improves its drainage, and during the summer assists to some extent in checking the evaporation of moisture from a light soil.

To the farmer, soils are classified largely on the basis of their texture. They are referred to as sandy soils, loam soils, or clay soils, and the texture can be roughly estimated by the feel of the soil when moistened and pressed between the thumb and forefinger. Thus a sandy soil feels loose and the separate particles are readily distinguished by feel and sight. Even if the soil is pressed together when wet, it does not retain its shape for very long and crumbles at the slightest touch. At the other extreme, a clay soil feels soft and soapy, and when pressed into a lump retains its shape and dries to a hard and solid clod. Loams, which are intermediate between sands and clays, are fairly smooth and plastic, and when wet form a lump which must be handled very carefully to avoid breaking it. These differences in texture are due to the varying proportions of sand, silt, and clay which the soils contain.

Sand consists of hard irregular-shaped particles which have no power of sticking to each other and which allow water to pass easily through them. The separate particles do not pack very closely together and there is a considerable amount of air space between them. As a source of plant nutrients, sand is practically useless and its function in the soil is to form a kind of framework to contain the more active soil constituents. The silt particles are also comparatively inactive, and being smaller, pack together more closely and produce a more compact soil.

The smallest soil particles are clay, which differs from sand and is not only smaller in particle size but is active both physically and chemically. Clay is described by the chemist as a colloid, a simple definition of which is a substance that is a semi-solid. Two common colloidal substances are glue and white of egg. It is the colloidal nature of clay that gives it the property of plasticity, and enables the particles to become attached together. A mass of clay will not allow water to pass easily through it, and a soil with a high percentage of clay is very subject to waterlogging. But its power of binding together is of great importance in the formation of tilth in a soil, and its ability to retain moisture affects the water supply of plants. A soil that has no clay fraction is little more than a heap of sand and is useless for farming. Clay is an essential constituent of soil, but if present to excess it causes great difficulty in cultivations. The soil adheres to the implements working in it and this slows up the rate of work. Too much clay also causes the formation of large clods, which are quite unsuited to plant growth, and the soil cannot be cultivated in wet weather

without damaging it. Clay expands when it is wetted, and shrinks when dry, and a clay soil is almost always full of large cracks during the summer months.

Clay is also active chemically in the soil, and this property is of great importance in farming. It has the power of combining with certain chemical elements, for example, potassium, and this combination prevents the elements from being washed out of the soil. When the clay in a soil is combined with calcium, the soil is more easily cultivated, and forms the small crumbs needed for the seed bed. The larger particles make the soil less retentive of moisture.

From this account of the respective properties of clay and sand, it will be seen that the relative amounts of clay and of sand in a soil have a considerable effect upon its character. The content of clay and sand can be used to classify soils. A soil with more than 30 per cent of coarse sand is light and sandy, and a soil with more than 35 per cent of clay is heavy and sticky. The ideal soil from a farmer's point of view is a loam which might contain about 20 per cent of coarse sand, 15 per cent of clay, and the remaining soil particles in the form of fine sand and silt. This amount of sand ensures easy working and reasonable drainage, whilst the clay is sufficient to hold the soil together and retain a supply of moisture to prevent the crops suffering from drought in the summer. In practice, all grades of soil from sandy to clayey are found, and the farmer uses such terms as sandy loams, medium loams, and heavy loams to describe the different degrees of texture.

Although for the most part the mineral content of a soil is inactive, it contributes in some respects to plant nutrition. Certain minerals from which the soil has been derived contain a proportion of phosphorus and potassium, and, as these minerals are broken down, the plant nutrients contained in them become available for absorption by the roots. But the plant nutrients in the mineral matter of the soil are not easily made available, and may be regarded as a reserve of fertility, a part of which becomes available in very small quantities each year.

The size and character of the soil mineral particles affect its air and water content. A soil with a high percentage of coarse sand has large spaces between the particles. Such a soil is free-draining in winter, but liable to suffer from drought in the summer. A soil with a higher percentage of the smaller-sized particles has correspondingly less air space, and retains a higher moisture content. The water in the soil exists as a film surrounding the separate particles : if the particles are small, there is a greater surface area for the retention of water. This is easily understood by comparing the amount of water attached to a stone

when wetted with the amount the same stone has when it is crushed to a powder and wetted. When a soil contains a high percentage of clay, the absence of pore space and the retention of water may interfere with cultivations and with plant growth unless the particles of clay combine together to form a crumb structure, which is equivalent to increasing the particle size. The formation of crumbs depends upon the chemical elements with which the clay is combined. A clay combined with calcium, which comes from lime, gives a very satisfactory crumb structure, and without lime a clay soil could not be cultivated to produce a seed bed. If the calcium content of a clay is replaced by sodium, as when a field is flooded by salt water, the clay becomes sticky and unworkable.

Thus, the mineral portion of the soil serves a variety of purposes. It provides the framework of the soil, it determines the ease of cultivations, and influences the air and water content of the soil. Further, it plays some part in providing the nutrients required to support plant growth.

Organic Matter

In addition to their mineral constituents, all soils contain some material derived from the decomposition of living matter, and this is referred to as the organic matter of a soil. It differs from the mineral portion in that it can be destroyed by heat, and one method of estimating the organic matter of a soil is to burn a known weight of soil and to calculate the loss of weight. It consists partly of recognizable bits of plants such as leaves, roots, or straw, but most of the organic matter in the soil is decomposed into a black shapeless material, which is closely mixed with the mineral particles and is difficult to separate. When in this form, the organic matter in a soil is known as humus. It is black in colour and a high percentage of humus darkens the colour of a soil. Garden soils are usually richer in humus than farm soils and are correspondingly darker in colour. One of the chief differences between the surface soil and the subsoil is the darker colour of the top layer, and this is due to the fact that the top soil contains humus, whilst the subsoil is lacking in it.

Under natural conditions, the organic matter of a soil comes from the remains of plants that have been growing in it. At the end of the growing season the plants die down, and the dead leaves and flowering stems become incorporated with the soil. Earthworms play a very important part in getting this form of organic matter into the soil. Under the conditions of arable farming, the organic matter of the soil is maintained partly by ploughing in crop remains, such as cereal stubbles and seeds leys, but princi-

pally by the application of farmyard manure. In certain circumstances, crops are grown specially to be ploughed into the soil, a practice known as green manuring.

Soil Bacteria

When organic matter is added to the soil, a part undergoes oxidation by bacterial action resulting in its rapid disappearance, and the rest is broken down more slowly and turned into humus. Oxidation is a process that has much in common with the burning of organic matter, though it takes place much more slowly. The plant remains are turned into carbon dioxide and water, and the plant nutrients contained in the organic matter are released. The oxidation of organic matter in a soil is favoured by conditions of warmth, moisture, and an abundant supply of air. These conditions are more likely to occur in a light and sandy soil, and the cultivation of a soil increases aeration and speeds up oxidation. Under farming conditions, the maintenance of organic matter is more difficult on light than on heavy soils, and on arable land than on grassland.

The decomposition of organic matter in the soil is entirely the work of the micro-organisms that are present in the soil. They are small—invisible except under the most powerful microscope—and can be numbered by the million in each cubic inch of soil. It is of the greatest importance to realize that the soil is not a mass of dead earth in which plants grow, but that it is itself a living medium, and supports an entirely separate population of living organisms consisting of bacteria and fungi. These organisms have a profound and vital influence on soil fertility, for it is by their activities that the organic matter in the soil is broken down to yield plant nutrients, Without the action of these organisms, plant life would be impossible.

The micro-organisms in the soil are of two main kinds. One group functions in the absence of air, and the other needs a supply of air. The second group is of the greater importance to the farmer, and is responsible for the breaking down of organic matter. In the course of this breakdown, the plant nutrients in the organic matter are changed into a soluble form in which they are absorbed by the growing plants. This is of particular importance in the case of nitrogen, which is present in a plant as protein, and is ultimately made available in the form of nitrates by bacterial action. The bacterial activity in the soil continues whether the land is being cropped or lying idle, and one advantage of allowing a field to lie fallow is that, during this period of rest, a reserve of available plant food, especially nitrate, is built up and is used by the crop that follows.

Certain conditions are necessary if the soil bacteria are to work to the best advantage. As they are living organisms, the soil must contain sufficient air to provide oxygen for their respiration, and there must be a supply of moisture. The lime content of the soil must be adequate to counteract any acids that may be produced. The bacteria also need a suitable temperature at which to function. During the winter, bacterial activity in the soil is practically at a standstill and reaches its highest point in the early summer. At the hottest part of the summer, bacterial activity slows down somewhat, due partly to excessive heat and partly to an absence of moisture.

Certain bacteria found in the soil may be harmful. If a soil has a high percentage of organic matter but is inadequately supplied with air, a group of micro-organisms flourish that turn the nitrogenous compounds into nitrogen gas which is lost from the soil. Fortunately the necessary conditions for this to happen are not often met with under ordinary farming conditions.

Another activity carried on by certain bacteria in the soil is of outstanding importance to agriculture, and results in the fixing in the soil of nitrogen from the air and storing it for the use of the succeeding crops. This fixation of nitrogen is done by special strains of bacteria, which attach themselves to the roots of leguminous plants, including peas, beans, clovers, lucerne, and sainfoin. The presence of the bacteria can be detected by the swellings found on the plant roots, and it is essential for the growth of these legumes that these swellings should develop. Once the plants have been established, the bacteria on their roots absorb gaseous nitrogen and the plants are then independent of other sources of nitrogen for their growth. Where a leguminous crop is grown on a soil for the first time, it may be necessary to introduce the particular strain of bacteria with the seed. This is referred to as inoculating the seed, and is often done with the seed of lucerne to ensure its satisfactory establishment. The relationship between the plants and the bacteria is one of mutual advantage. The bacteria live on the sap of the plant and provide in return a supply of nitrogen for the plants. This process of the fixing of nitrogen by leguminous plants is of great importance and significance to agriculture. When the remains of these plants are incorporated with the soil they add to the plant nutrients in the soil. There is scarcely any rotation of crops that does not include at some point a leguminous, or pulse, crop.

There are a number of less beneficial organisms in the soil, particularly a group known as protozoa, which feed on the bacteria in the soil. When crops are grown in a greenhouse, it is a common practice to sterilize the soil by heat or by chemical means, which

destroys almost all the organisms in the soil. The beneficial bacteria multiply more rapidly than the others and the amount of food material made available for the plants is increased. Sterilization of the soil destroys many of the organisms which in the high temperature and moist conditions of a greenhouse would multiply to an undesirable extent.

Properties of Organic Matter

The account that has been given of the part played by organic matter and its decomposition by bacteria has emphasized the important effects of organic matter on soil fertility. One function of organic matter is to yield a supply of plant nutrients in a readily available form. Organic matter has an equally important effect on the physical condition of the soil. The black material known as humus is not so sticky and plastic as clay, and, unlike sand, it is capable of retaining water. A proportion of humus in a clay soil makes it more open and helps to improve its drainage, whilst in a light soil humus increases the power of the soil to retain moisture. In this way, humus prevents both clay and sand from developing their worst characteristics in a soil, and helps to improve either type of soil. Organic matter influences the texture of the soil and assists cultivations as well as increasing the capacity of the soil to grow good crops.

It is not possible to give any definite figures for the percentage of organic matter in a soil. The proportion depends on many different factors, such as the amount added to the soil, the rate of oxidation, the degree of decomposition to humus, and the type of farming. It rarely falls below 2 per cent even on very poor soils, but a more common figure for the average farm soil would be from 5 to 7 per cent. In peaty soils, the percentage is extremely high, as these soils have been derived almost entirely from the accumulation of decayed vegetation under marshy conditions. These soils are deep black in colour and their content of organic matter may be as high as 60 per cent. They are extremely fertile and once they are drained present little difficulty in farming, either in respect of capacity for plant growth or in cultivation.

"Lime" in Soils

"Lime" is a term used rather indiscriminately to cover a wide variety of substances containing the element calcium, and in reference to the soil is often used as meaning calcium itself. Modern usage tends to restrict the use of the word "lime" to the compound known chemically as calcium oxide and generally referred to as quicklime. When quicklime absorbs water it forms the substance

known as slaked lime. Limestone and chalk are two forms in which calcium compounds are found naturally and are known as carbonates of calcium or carbonates of lime.

The calcium compounds found in the soil are of great importance and may be considered as a part of the inorganic matter, but they are mentioned separately because of their special functions. Every year there is a loss of calcium from the soil not only in the crop but to a much greater extent in the drainage water. Calcium exists in the soil in two main forms. It may be combined with the clay colloids, and in this form is referred to as active or exchangeable calcium. There may also be a reserve of calcium carbonate, which can be detected by a fizzing when a sample of the soil is mixed with an acid. A soil that contains a reserve of calcium carbonate may be regarded as having sufficient exchangeable calcium. The absence of a reserve does not necessarily imply that a soil needs liming at once, as it may contain enough exchangeable calcium to meet its immediate requirements.

As water passes through the soil it removes calcium, and while the soil has a reserve of calcium carbonate these losses are met from the reserve. When this is exhausted further losses in the drainage water result in a reduction in the amount of exchangeable calcium, and if this continues it leads in time to the development of acidity. The amount of exchangeable calcium present in a soil depends on the percentage of clay and humus, and light sandy soils are liable to develop acidity more rapidly than clay soils. On the other hand, it requires a greater amount of calcium to bring an acid clay soil into a neutral condition because there is more clay to absorb the calcium than in a light soil.

The acidity of a soil is measured on a scale known as the pH scale, the figures on which give a measurement of the degree of acidity or of the opposite reaction alkalinity. A pH figure of 7 shows that the soil is neither acid nor alkaline, and in this condition it is described as being neutral. Figures above 7 show that the soil is alkaline, and the upper limit of pH, or alkalinity in soils, in Great Britain is about 8. Figures below 7 indicate that the soil is acid and the greatest degree of acidity shown by farm soils is about 4. Practically all farm crops would fail to grow in soils with a pH of less than 4. Plants differ widely in their ability to grow in conditions of acidity. Rye tolerates a pH as low as 4, potatoes and oats grow satisfactorily at 4·5, whereas on most soils sugar beet and barley are almost certainly a patchy crop at any pH below 6. Soil conditions are so variable that it is impossible to give figures that apply to all soils and the figures given indicate the possible ranges. It is also possible to estimate the amount of calcium that can be absorbed by a soil and from this is calculated

the amount of lime that should be added to a soil to bring it into a neutral condition.

Some of the calcium in the soil is required as a plant nutrient, though the amount used for this purpose is comparatively small. Crops vary in their need for calcium and a failure of leguminous crops, especially clover, is one of the first indications of a shortage of calcium. But calcium compounds have a far greater effect on the soil than on the crop and are of particular importance in heavy clay soils. Their effect is primarily connected with the physical condition of clay soils. When clay is combined with calcium it forms crumbs or aggregates which keep the soil in a friable condition. The soil is more easily cultivated and is less retentive of moisture. If there is no reserve of calcium, the clay gradually loses its calcium and the soil becomes sticky and difficult to work, and remains wet in winter and bakes hard in summer. The absence of lime and the development of acidity affects the micro-organisms in the soil responsible for the breakdown of organic matter. They are unable to function under acid conditions and extreme acidity leads to an accumulation of undecomposed organic matter.

Soil Types

It is now possible to summarize the various constituents of soil. In bulk, it consists of mineral matter composed of varying proportions of sand, silt, and clay. A certain proportion of the soil is organic matter, which depends upon the innumerable micro-organisms for its decomposition, and which has both a physical and a nutritional rôle to fulfil. The physical condition is affected in the main by the mineral constituents and they are in turn affected by the presence or absence of lime. The soil must have a supply of air and water, and this is governed by the size of the mineral particles and the amount of organic matter present.

On the basis of these characters, the soils available for farming may be classified into five main groups ; viz., clay soils, loams, sandy soils, chalk soils, and peaty soils.

Clay Soils. In general clay soils contain more than 30 per cent of the clay fraction and also a high percentage of the small fractions of silt and fine sand. Their content of coarse sand is very low. Soils of this type are sticky in texture, and air and water do not move very freely in them. They should not be cultivated when they are wet, as this causes the surface to puddle and makes the soil even more impervious to water. When these soils dry, they have a tendency to form large clods that are hard and almost like rock and cannot be broken down to form a fine seed bed. If this happens in the spring, the land is useless for the remainder of the season. Grassland on clay soils should not be grazed by stock in

wet weather because of the damage done to the surface. The worst disadvantages of clay soils are considerably reduced by the presence of adequate supplies of lime and organic matter. Clay soils invariably display large cracks during hot dry seasons, but they retain moisture and withstand conditions of drought. Because of their relatively poor aeration, the organic matter supplied in the form of farmyard manure persists for a long time.

LOAM SOILS. Loam soils contain less clay and more coarse sand than a clay soil; they may be described as all-round soils and may be used to grow almost any crop. They have the advantages of both clay soils and sandy soils, with none of their more serious disadvantages. Their content of coarse sand makes them easy to cultivate, keeps them well supplied with air, and prevents them from becoming waterlogged. When organic matter is applied to them, it decomposes quickly enough to yield its plant nutrients within a reasonable time. The clay which they contain assists in the retention of moisture and the crops growing on these soils withstand moderate periods of drought. Care must be taken not to cultivate these soils when they are wet, because of their clay content, but they quickly dry into a suitable condition for cultivating. Loams vary in their content of clay and sand and are further classified as heavy loams, medium loams, and light loams. These soils are among the most valuable from the point of view of farming.

SANDY SOILS. Sandy soils contain only a small percentage of clay and consist for the most part of relatively large soil particles; they have an open texture. They are easily drained but are liable to dry out in periods of drought. The soil particles consist largely of minerals that are highly resistant to weathering and sandy soils are accordingly poor in plant nutrients. Their open texture means a plentiful supply of air, and organic matter disappears rapidly after application. They are often referred to as hungry soils and need constant applications of organic matter to keep up their fertility. There is no danger of puddling sandy soils, and cultivations can be carried out on them at almost any season of the year. They offer little resistance to the passage of implements and for this reason are often known as light soils, in contrast to clay soils, which are described as heavy because of the additional power needed to draw the implements through them.

CHALK SOILS. These are found in parts of the country where the underlying rock is pure chalk. These soils may contain from 10 to 50 per cent of carbonate of lime, and the top soil is usually thin and shallow with the pure chalk immediately underneath. They are easy to cultivate and drain freely, but the surface puddles if cultivated when wet. When the surface dries it becomes hard

and difficult to break up. Organic matter oxidizes rapidly in chalk soils, and regular and heavy dressings of farmyard manure have to be given.

Peaty Soils. These are of two main types. The true peat soils have been formed in places where there has been an accumulation of organic matter under waterlogged conditions, resulting in a very sour type of humus. Before they can be used for farming, they must be drained and well limed. Fen soils have been formed under marshy conditions, often at the mouth of a river. These soils cannot be used for agriculture until the area has been drained. Soils formed from reclaimed fenland are highly fertile and very friable and their high content of organic matter makes them almost sooty in appearance. The soils are easily cultivated and the system of drainage ensures an ample supply of water at a constant depth below the surface of the soil. The high organic matter content ensures a good supply of plant nutrients. Fen soils are capable of growing exceptionally good crops and are probably the most fertile soils found in the British Isles.

Chapter 3

SOIL MOISTURE AND LAND DRAINAGE

AN adequate supply of water is of the utmost importance for the growth of plants, and the water available for plant growth is one of the factors determining the comparative ability of soils to produce crops. A large number of soils are described as being infertile because of some problem connected with water. Some soils suffer from a shortage of water, and others have to deal with an excess. The water needed for plant growth comes from the rain that falls on the soil, and what happens to the rain will determine whether the crops make full use of the water.

Soils possess two properties that are of importance in the supply of water. On the one hand, they hold up water, and their capacity to do so is largely dependent upon the amount of clay and humus they contain. They also allow water to pass through them to the lower levels, where it may be available for plant growth if the roots can make contact with it. In many cases the water may penetrate very deeply and be lost so far as plant growth is concerned. The rate at which water percolates through a soil depends upon the size of the soil particles, and is more rapid in a sandy soil than in a clay. If the clay has a good crumb structure, the permeability of the soil is increased.

Rainfall and Water Supply

When rain falls on to the soil, a proportion of it may never enter the soil, but runs off the surface and finds its way into ditches and streams. The remainder penetrates into the soil, and part is absorbed and transpired by growing plants ; the balance soaks through the soil and eventually reaches a level in the soil known as the water table. This is the point at which all the spaces between the soil particles are completely filled with water. If a hole is dug in light sandy soil in winter, the water table can often be found about two or three feet below the surface. During the winter, the amount of water transpired by plants is almost negligible, and most of the rain either runs off the surface or penetrates the soil and gradually drains away. In summer time, the amount of transpiration is greatly in excess of the amount of rainfall, and the soil becomes very dry. Unless the plant is able to draw on the underground supply of water, a point may be reached where there is insufficient moisture for growth and the plants begin to droop or wilt for lack of water. During the summer, there is an appreciable loss of water by evaporation from the soil.

In a clay soil, the spaces between the soil particles are much smaller, and when clay is wetted its colloidal matter swells and virtually fills the particle space, so that water cannot pass through into the subsoil. Consequently, there is no clearly defined water table in a clay soil, and the surface soil acts somewhat like a sponge. When it has absorbed water to the limit of its capacity, pools form on the surface, which is an obvious sign that the soil is waterlogged.

There are three main factors governing the supply of water available to the plants growing in the soil. Firstly, the total amount of water available depends upon the amount of rain that falls, and also on the time of the year when it falls. If all the rainfall occurs during the winter, much of it runs off the surface or penetrates into the lower layers of the soil, whereas, if some of the rain comes when the plants are growing, a greater proportion will be used by the plants. The second factor is the capacity of the soil to hold water. A clay soil, or a soil with a high percentage of humus, absorbs more water, and holds it in the upper layers, than a light and porous soil. Lastly, the supply of water for plant growth is increased if plants have deep rooting systems which take in water from the lower levels of the soil.

The farmer is faced with two problems connected with the water supply of a soil. In the first place, he must make certain that there is no excessive amount of water in the soil, as that diminishes the air supply to the roots. On the other hand, water is a critical factor in plant growth and he endeavours to maintain as much water in the soil as is consistent with adequate aeration. The problem varies with the type of soil. The farmer on a light sandy soil aims at conserving moisture, whereas on a heavy soil the removal of excessive moisture by drainage is essential for good crops.

The conservation of water is partly a matter of cultivations. Care must be taken to avoid unnecessary cultivations which might lead to loss of moisture. This danger is most likely to arise in the spring, especially if cultivations are carried out too late. Late ploughing in spring, an excessive use of the cultivator, and potato ridges left open for too long are all ways in which valuable moisture may be lost. The addition of organic matter to light soils is another method of increasing the capacity of a soil to absorb and retain more water. The killing of weeds affects the water supply indirectly, because weeds, like other growing plants, are continually transpiring water taken from the soil and water used by weeds cannot be used by the growing crop.

Land Drainage

The effects of excessive water and waterlogging are very serious for the farmer. It has already been pointed out that excess water

leads to a shortage of soil air. It adds greatly to the difficulties of cultivation, and encourages plants to develop a shallow rooting system. This is evident with crops growing in a wet soil during the winter ; and their roots only penetrate a short distance into the soil. When summer comes and the soil dries out, the plants are unable to survive because their roots are not deep enough to be in contact with the water lower down in the soil. One of the indications that a field needs drainage is the presence during the summer months of patches where the crop has died or turned brown during a drought. Patches with a burnt appearance are a common occurrence on grassland that is in need of drainage. The presence of too much water affects the rate at which a soil warms up in the spring. More heat is needed to raise the temperature of water than that of an equal weight of soil, and a dry soil always grows earlier crops than one which is wet, because of the more rapid rise in temperature. Another effect of excessive water is the development of plants of little or no value to the farmer. The presence of rushes, and of a creeping grass called water grass, are certain indications of the need for drainage. Waterlogged pastures cannot be grazed in the winter because of the danger of ruining the surface of the soil, and where sheep are run on undrained grassland, they are liable to attacks from a parasite called the liver fluke, which passes one stage of its life history in a small water snail which only survives on a wet pasture.

The disadvantages of undrained land are such that it cannot be used for farming until the surplus water has been removed. The movement of water in a clay soil can be improved to some extent by the formation of a crumb structure, and this is encouraged by the use of lime. This has only a limited effect, and for most clay soils, more drastic action is necessary. The operation used to remove water from the soil by artificial means is known as drainage. It is an ancient practice, and in early days was done mainly by surface drainage. Much of the heavy clay land in this country is still in the form of ridge and furrow, with ridges about 10-15 feet wide which give a corrugated appearance to the surface of the field.

Tile Drainage

The practice of drainage below the surface is also old, and, in its earliest form, consisted of digging a trench and filling it with bushes or stones to act as a channel into which the water could pass from the surrounding soil and flow away into the nearest ditch. Later, the bushes or stones were replaced by a hollow channel built up of bricks, and in the early part of the nineteenth century, the cylindrical tile drain was invented. This system is still practised and is known as tile drainage. A large acreage of

heavy land in this country was drained by this method during the nineteenth century, but since the war of 1914-18 it has become too expensive in relation to the economic condition of agriculture. A good system of tile drainage might cost up to £20 an acre, which was in many cases more than the value of the land itself.

The procedure of putting in a system of tile drain consists of digging a number of trenches and laying the draining tiles along the bottom of the trenches. The expensive item in tile drainage is the digging and filling in of the trenches, especially if this has to be done entirely by hand labour. Some economy in cost can be effected by using a plough to take out the first few inches, and machines are now used for the excavation of a suitable trench. Even where a machine is used, the final levelling of the bottom of the trench has usually to be done by hand, and careful finishing is essential if the drain is to slope or fall evenly towards the ditch. The tiles themselves are cylindrical in shape and made of hard burnt clay, and each tile is about 12 to 15 inches long. They are placed end to end along the bottom of the trench, and, as they are not joined together, great care must be taken to ensure that they are placed correctly, with no danger of displacement. The water enters the drain at the points where the tiles touch each other, and the spaces between the tiles must be almost negligible, so that water seeps in, but not much soil or silt gets into the drain. When the tiles have been laid, it is sometimes the practice to put a covering of brushwood over them before filling in the trench. This increases the capacity of the drain to remove water.

When a field is to be drained by this method, the lay-out of the drains has first to be decided. There are two main forms of lay-out. One method is to have a regular system of drains covering the whole field; the other is to put in special drains to take the water away from wet places in the field. The drains in a system for the whole field may be laid in the form of a grid, with each of the drains leading into one main drain, which in turn takes the water to a ditch. Another system is to put the drains in the form of a herring-bone, with a number of main drains fed by minor drains. The second point which has to be decided is the depth at which the drains are to be laid. If they are put too deep, the water takes a long time to reach them; and as it is the wetness of the surface soil which causes the trouble, deep drains are not very effective. Many old drainage systems were put in so deeply that they have not fulfilled their purpose. The tiles must not be near the surface, or they are liable to be displaced when the land is being cultivated. Modern practice in tile draining is to put the drains from 30 to 36 inches below the surface in a clay soil. Tile draining is sometimes done on fairly light soils in which, for some

reason, the water table is too high. In such cases, the drains may be placed a little deeper, and the level of the water table drops until it is just below the depth of the drains.

Drainage tiles are made in different sizes varying from $2\frac{1}{2}$ in. to 6 in. in diameter. It is important not to use a tile that is too small, and tiles less than $2\frac{1}{2}$ in. are rarely justified. The size of the tile to be used depends mainly on the area of land to be drained, and an approximate guide is to use a 3 in. tile for an area of two to three acres, a 4 in. tile for six acres, and a 6 in. tile for 18 acres. In practice, the minor drains have smaller tiles and a larger size of tile is used for the major drains which take the water from several minors. The figures given above relate to the sizes needed for the main drain leading into the ditch. The fall, or the angle at which the drain slopes to the ditch, needs some attention, though it is not a matter of great importance as long as the slope is all in the direction of the ditch and there are no sudden changes in the angle of fall.

The point at which the drain enters the ditch is known as the outfall, and this is an important point of the system. The pipes from the drain should not enter the ditch merely by passing through the bank or side of the ditch. There is a danger that the sides of the ditch may collapse or the bank may be washed away, or destroyed by vermin. If this happens, the drains are unable to discharge the water they have collected and the field becomes waterlogged once more. The only satisfactory method of making an outfall is to fix a long length of pipe from the drain into a mass of concrete or to build a buttress of bricks. It is more satisfactory to use a glazed pipe for the outfall, as this is less likely to be damaged by frost. The end of the pipe should be covered with a piece of wire netting or a metal flap to prevent rats from getting into the drain.

The installation of a system of tile drains is best done at the end of winter. The subsoil is then wet and it is less laborious to dig clay when it is wet than when it has dried hard. It is also easier to make a firm bottom to the trench when the subsoil is wet and plastic. In practice, work on drainage is more frequently carried out in winter at a time when labour can be spared and when there are not so many other urgent tasks to be done.

Once a system of tile drains has been installed, it should continue to function efficiently for many years. A number of things may go wrong and cause a breakdown in the system. Some of the tiles may get broken or moved out of place, due to the bad laying of the tiles, or to the passage over the drain of a heavy tractor or threshing machine. The presence of a wet patch may indicate that some of the tiles have been displaced, and the remedy is to

dig up that part of the drain and relay or replace the tiles. A constant danger with a system of tile drains is that they may get blocked or silted up with particles of soil washed into the drain in the drainage water. The tendency to silting is increased where there is a sudden change of fall, or where one drain joins another at too sharp an angle. Even the outfall may, in some circumstances, get silted up and cause the whole system of drainage to fail. Drains are also liable to be blocked by the roots of trees. Trees often grow in the hedgerow near the ditch, and if a root enters the drain, it may grow several yards along the drain and cause a complete blockage. The remedy for breakdowns of this nature is to take up the tiles, clear out the cause of obstruction, and relay the drain.

It is essential that the ditch itself should be cleaned out regularly so that the water gets away rapidly. During periods of depression in farming or when labour is scarce and expensive, there is a temptation to neglect work of this kind, and ditches become filled up with silt and mud and overgrown with vegetation. It is a fairly common experience to find that an apparently undrained field is wet because the ditch is blocked, and when this has been cleaned out and the outfalls uncovered, the system of drainage begins to function efficiently once more.

Wherever a system of tile drainage is installed, it is a wise precaution to make a detailed plan of the field showing the position of every drain and the outfalls. Such a plan is extremely useful when trying to remedy breakdowns in a system, and the renovation of existing systems is much simpler if plans of the drains are available. The position of the drains is best recorded on a 25 in. ordnance map, which should be kept in a safe place for future reference.

Mole Drainage

This is an alternative method used for draining certain types of land and has the great merit that it is considerably cheaper to carry out than tile drainage. It consists of making a series of channels in a clay subsoil by drawing a specially designed implement through it, and the persistence of the channels depends upon the plastic nature of clay. This system of drainage is practicable only on soils with a subsoil of pure clay containing no patches of gravel and no large stones. The implement used to make the channels is called a mole-plough and consists of a steel "mole"—shaped like a bullet or shell and fixed to a strong steel coulter which passes edgeways through the soil, leaving a narrow slit and a round or slightly oval channel at the bottom. Behind the mole is a "bob" of slightly larger diameter which helps to make the sides of the channel firmer and less likely to collapse. The part

of the implement that works below ground is attached to a stout framework mounted on wheels. When mole draining was first adopted, the mole plough was drawn across the field and back by a steel cable, the power being provided by two stationary steam engines, one at each side of the field. The introduction of the track-laying tractor of high power has provided another and quicker method of pulling a mole plough, and tractors are far more commonly used to-day than steam engines.

As the mole plough proceeds along the field, it not only forms the mole channel itself, but it exerts a general loosening effect on the soil on each side of the drain. The result of this loosening is to make the soil more porous and cause the water to seep towards the slit and channel ; when it reaches the channel, the water passes along it to a main drain and eventually to a ditch. The channels are drawn at a distance of from 9 to 15 feet from each other, but if the land to be drained is in ridge and furrow, the channels are drawn in the furrows and may be only three or four feet apart. Mole drains work at depths varying from 12 to 30 inches, but when the channels are too near the surface, they do not last long, as the clay at this depth is not so plastic as that lower in the subsoil. The minimum depth to draw the channels is 15 inches and the most common practice is to draw them at a depth of 24 inches. The "moles" are of different diameters, the usual diameter being three inches.

Mole drains should not be drawn to discharge directly into a ditch, but should lead into a main tiled drain. This is done by placing a tiled main across the bottom of the field at a depth below that of the mole drains and drawing the moles over the top of the main. The main drain is connected with the ditch. It is best to use a tiled main, as this can be put in as a permanent drain, and fresh mole drains can be drawn over it when required. The life of a system of mole drains depends partly upon the care with which they are drawn. It is important that the plough is set correctly so that there is no tendency for the mole to pass unevenly through the soil with the point higher than the back, or with the point digging into the soil. The length of life is also influenced by the nature of the subsoil, which affects the persistence of the channel. Mole drains may last for periods of 5 up to 15 years. The cost of the operation has been so reduced that it should now be regarded as a routine cultivation to be carried out once every four or five years ; and for heavy soils on a pure cla subsoil, it is a most efficient form of drainage.

Fields suitable for mole draining can be nearly flat, but should have an even slope, and the moles are drawn parallel up and down the slope and passing over the main drain across the bottom of the

field. In very large fields it may be necessary to have more than one main drain. In some cases the tiled main may be replaced by a series of main drains drawn with a mole plough a little deeper than the moles coming down the slope. Main drains drawn in this way are not as substantial or as permanent as ones laid with tiles.

A system of mole drains can be drawn at a cost of about £3 an acre. They can be drawn at almost any time of the year, but the most satisfactory time is in the spring. The surface of a clay soil is moderately dry at this time of the year and is not unduly damaged by the plough and the tractor. Moreover, the subsoil is still wet and consequently more plastic, which enables a better and more permanent channel to be drawn.

Other Forms of Land Drainage

In certain circumstances, it is not possible to use either tile drainage or mole drainage, and some system of surface drainage has to be adopted. In the west and north of England, it is a common practice to provide heavy land with a waterfurrow which takes the water off the surface of the land before it penetrates into the soil. This method is often adopted as supplementary to an underground system of drainage, especially where there is a high winter rainfall, and when the land has been sown with a cereal crop in the autumn. The channels are made by ploughing two furrows away from each other at suitable intervals along a field, and it is important that the furrow should lead into a ditch, and as this cannot be done by a plough, the digging of the water furrow must be completed by hand.

Soils that are free draining because of their open texture do not require any underground system of drainage, but if the land is low lying, it may become waterlogged unless a series of ditches is dug around the different fields. The water passes easily through the soil and seeps outwards towards the ditches and then flows away. The drainage of the Fen country is a special problem, and is done mainly by a system of ditches round each field that lead into main dykes. Land in the fen is often below sea-level and the water from the dykes has to be pumped into a river, which is kept at a higher level than the surrounding land by means of strong and wide banks of clay. The maintenance of ditches and dykes, and the cost of pumping the water into the river, has to be paid out of a local drainage rate, and this is a considerable item in the cost of farming in the Fens.

Open ditch draining is also used to remove excessive water from hillsides that are being used for sheep grazing, or for planting with forest trees. It is usual to dig the ditch on the diagonal of the

slope, as this prevents the water flowing down too rapidly and carrying away a considerable amount of the surface soil.

Mention has been made of the ancient practice of putting fields in ridge and furrow to assist drainage. A modification of this practice is still in use in certain parts of the country, particularly in Essex and Suffolk. The land is ploughed in a special manner so that it is left in ridges from seven to eight feet in width, with an open furrow between them. These ridges are known locally as 'stetches,' and the local implements are designed so that the horses drawing them walk along the furrows and do not tread on the 'stetches' themselves.

This method of drainage has to be adopted on certain soils because of their somewhat peculiar texture. The soils are heavy clays, but contain, in addition to the clay fraction, a relatively high proportion of the next smaller-sized particles known as silt. This fraction has no plastic qualities, and mole drains cannot be drawn in the subsoil. It is also impossible to use a system of tile drains, because the drainage water carries a great deal of silt into the tiles and the drains get blocked in a very short time.

The importance of having agricultural land properly drained cannot be over-emphasized. From the account that has been given of the effect of too much water in the soil, it will be realized that a farmer who attempts to carry out the principles of good crop husbandry on ill-drained land is certain of failure. Undrained land cannot be properly cultivated, and a crop cannot utilize lime and fertilizers if they are applied to land that is too wet. Money spent on seed of good quality is only wasted if the seed is sown in a waterlogged soil. It is for these reasons that drainage has been described as the first of all improvements.

Chapter 4

MAINTENANCE OF FERTILITY

THE fertility of a piece of land may be defined as its capacity to fulfil the conditions necessary for farm crops to grow, and, with the aid of good husbandry, to give satisfactory yields. The only standard by which the fertility of one piece of land can be measured and compared with that of another is its capacity to continue giving satisfactory yields over a number of years. Farmers often describe land by its ability to yield, particularly in terms of quarters of wheat, and refer to a farm as being "three-, four- or five-quarter land," and this is a rough guide to its level of fertility or capacity for yielding. The capacity of the land to give good yields has an obvious influence on the profitability of farming. Thus in times of high and profitable prices, land with a low level of fertility will be brought under cultivation, but in a period of falling prices, land of low fertility is the first to go out of cultivation. The maintenance of fertility is one of the great responsibilities of the farmer, and he should be ever conscious that he is acting for the time being as the guardian of the land. Both his farming success and his continued prosperity are based, not only upon the use, but upon the preservation of the basic wealth that comes from the fertility of the land. If this is not duly safeguarded the farmer himself, or his successors, will eventually come to disaster.

In more primitive systems of farming, the fertility of land was maintained by a process of rest and recuperation. Farmers did not settle permanently in one place, but selected a piece of land and cultivated it for a few years until the fertility began to fall and the yield of crops decreased. The land was then left, and the farmers moved to another piece of land. This was a system of farming known as shifting cultivation. After the land was abandoned, it returned to its natural vegetation and, in the course of years, its fertility was restored. This happened because the soil retained sufficient fertility for wild vegetation, and this was able to abstract every year a small amount of plant nutrients from the soil. When the plants died down and decomposed, these nutrients were returned to the soil. A small proportion of plant foods was lost each year in the drainage water, but this was more than balanced by the gains that came from decaying plant remains ; some of these plants contributed nutrients coming from the fixing of nitrogen from the air. In the course of years, there was an accumulation of fertility, of which the obvious indication was an

increase in the organic matter content of the soil. When the land was brought under the plough once again, it was capable of producing profitable crops. It is the accumulation of organic matter in virgin soils that enables them, when first brought into cultivation, to give high yields.

In time, shifting cultivation gave way to a more settled form of agriculture, and for many centuries land was farmed on a fixed sequence of crops. This sequence, or rotation of crops, worked on a basis of three years and consisted in the first year of an autumn corn crop, usually wheat, followed by a spring corn crop, which was barley, and then a bare fallow, after which the land was sown with wheat again. Thus the land was allowed to rest for one year in three, and this prevented the fertility from falling too rapidly. But this selection of crops was not sufficient to keep up the fertility, and the land gradually became less productive. In the eighteenth century, the introduction of clover and turnips made it possible to design a rotation of crops that would maintain soil fertility. By combining these crops with autumn and spring corn, the famous Norfolk four-course rotation was developed, which had a sequence of wheat, turnips, barley, and clover, and almost all modern crop rotations have been developed from it. Under the Norfolk rotation, the fertility of the soil was maintained partly by the feeding of the turnip crop to sheep, partly by turning the straw into farmyard manure and applying it to the root crop, and partly by growing clover, which added to the nitrogen content of the soil by the bacteria growing on its roots.

Losses of Fertility

The most obvious reason for a loss of fertility from land is the continuous growing of crops for sale off the farm with no replacement of the plant nutrients removed by the crop. The first indication of declining fertility is a decrease in yield, and, in time, there comes a point at which the yield is small but remains almost constant from year to year. This has been shown by experiments at Rothamsted, where a number of fields have been growing the same crop continuously for a large number of years. The fields have been well cultivated, but no form of manure has been added to the soil. The result has been that the crop yields have gone down until they have reached a fairly constant but low level, wheat and barley yielding $12\frac{1}{2}$ bushels an acre, mangolds $3\frac{1}{2}$ tons, and swedes $\frac{3}{4}$ ton. By modern standards, these yields are very low, but they prove that although fertility may be reduced below a level at which farming is profitable, it cannot be destroyed completely. It seems probable that the land could continue to give these low yields indefinitely. Every year, a small amount of

organic matter is returned to the soil by the ploughing in of crop remains in the form of stubble, plant roots, and weeds, and this decomposes to yield a limited supply of plant food. Added to this, a small proportion of the plant nutrients contained in the mineral matter of the soil becomes available every year.

There is also a loss of fertility from the land when livestock of any kind are kept and their produce sold from the farm. All growing animals need lime and phosphate for the formation of bone, and these elements must come from the crops consumed and are thus ultimately drawn from the soil. The production and sale of milk also remove considerable amounts of phosphate and potash from the land, and in time this reduces fertility.

It is not sufficient for the maintenance of fertility just to replace the various elements that may be removed by growing crops or by the stock kept on the land. There are important losses of plant nutrients every year in the drainage water. This is especially so in the case of nitrate, which is the soluble form of nitrogen. Considerable quantities of lime are also lost every year by drainage. There is the additional loss of nitrogen that may result from the activities of denitrifying bacteria. It is important that these less obvious losses of plant nutrients should not be overlooked when considering the problem of restoring the fertility of the soil.

Gains of Fertility

When land is under grass for a number of years, there is usually an accumulation of fertility, because the absence of any cultivation of the soil leads to an increase in the amount of organic matter. But due care must be taken to ensure that the various elements removed by the livestock feeding on the pastures are replaced. Mere accumulation of organic matter, if accompanied by a loss of phosphate and potash from the soil, cannot justifiably be regarded as an increase in fertility. In this way, land under permanent grass differs from land left to its natural vegetation and not grazed. Only pastures that contain clover and receive regular applications of mineral fertilizers to replace losses are genuinely storing up fertility.

Under the conditions of arable farming, the return to the land of straw in the form of farmyard manure is not necessarily a gain in fertility unless the farmyard manure is made by livestock whose rations are partly made up of feeding-stuffs that have been purchased and brought to the farm. The consumption of home-grown feeding-stuffs retains rather than adds to the fertility of a farm, and even a policy of complete self-sufficiency in home-grown feeding-stuffs does not maintain fertility without the use of purchased feeding-stuffs or fertilizers. It is most important to realize

that so long as crop or stock products are leaving the farm, they are taking away elements of fertility that must be replaced by the use of purchased fertilizers or feeding-stuffs. This point is frequently forgotten in arguments against the use of fertilizers supplied in the form of chemical compounds. If they are not applied to the land, there must be a loss of fertility.

Fertility is also increased by the ploughing back into the land of crops and their residues, since the nutrients taken from the soil and, in the case of deep-rooted plants, from the subsoil, are returned in a form in which they are more easily used by the succeeding crop. This aspect of fertility is concerned with the availability of plant nutrients. The soil and the subsoil have a vast store of potential plant food that cannot contribute to fertility until it is in an available form. The practice of green manuring is another method of adding to the fertility of a soil. Certain quick-growing plants are sown especially to be ploughed back into the soil, thus returning in a more available form the plant foods they have absorbed. Green manure crops are often sown in the summer, when they grow rapidly, and absorb and retain soluble plant foods that might otherwise be washed out. When used in this way, green manuring is adding indirectly to fertility by preventing a loss of plant nutrients.

The importance of the leguminous plants in the increase of fertility has already been mentioned in an earlier chapter, but should be stressed again. They make a most important contribution to the increase of fertility by the absorption and fixation of atmospheric nitrogen. These plants carry out in the soil the same process that requires the most complicated machinery in the industrial manufacture of plant foods from atmospheric nitrogen.

Other Aspects of Fertility

So far, the fertility of a soil has been discussed only in terms of its content of the elements needed for plant nutrition. Other aspects of fertility are associated with water supply, physical condition, and freedom from weeds, which are partly inherent characteristics of a soil, but at the same time depend upon the practice of good husbandry.

A fertile soil must provide adequate supplies of air and water for the roots of plants and this depends in part upon the soil texture, though excessive water may be removed by drainage, and deficiencies of water may be made good by irrigation. The movement of water in a soil is governed to some extent by the physical condition of the soil. This is largely an inherent characteristic and depends upon the amount of clay the soil contains, but may be modified to a considerable extent by the presence or absence

of organic matter and of lime. Clay soils are naturally close and sticky in texture, but the addition of organic matter makes them more easily cultivated and less retentive of moisture, whilst lime assists in the formation of a crumb structure, which is needed to obtain a tilth. It follows that, unless a farmer maintains a clay soil in a good physical condition, he cannot utilize the fertility it possesses.

Light soils are inherently low in plant foods, but good farming may increase their capacity to grow good crops. The addition of organic matter builds up a reserve of plant foods and increases the retention of moisture. Their physical condition makes them easy to cultivate and they warm up quickly in the spring. These characteristics are often used to their best advantage for market gardening, and a sandy soil that might be of low productivity under ordinary conditions of mixed farming may be very fertile for market garden crops. In such a case, the fertility is almost entirely due to the method of farming adopted.

Land that is inherently fertile may be of low productivity for reasons of bad farming. If the control of weeds is neglected, the crops growing on the land suffer not from an absence of fertility but from competition with weeds. The intensive growing of the same crop on a piece of fertile land may not lower the fertility, but may cause the land to become infected with disease so that yields are lowered. In both cases, inherent fertility may not have been destroyed, but cannot be used to its best advantage.

Soil fertility is thus a balance of all the properties of a soil that affect plant growth. It consists partly of the inherent characteristics concerned with the supply of plant nutrients and the physical nature of the soil, and partly with factors associated with good husbandry and its influence on water supply, tilth, and freedom from weeds. The two aspects are sometimes described by different names, the inherent characteristics being called fertility and the other factors known as condition. The two aspects cannot be separated very clearly, but are based on the assumption that inherent fertility has developed naturally, and that condition has been produced by the efforts of those who have been farming the land. Fertility and condition both determine the capacity of land to grow good crops, and the distinction serves to indicate the extent to which the productivity of a farm is inherent or has been acquired.

Indications of Fertility

The factors that contribute to the fertility of land are so complex that it is impossible to assess fertility by a simple method of analysis in a laboratory. When a sample of soil is analysed, it is possible to determine the percentage of organic matter, and its content of

plant nutrients and lime. But the ultimate test of fertility is provided when the land is used for growing a crop, when the climatic and other natural conditions determine what use can be made of the elements of fertility it contains. A general indication of the fertility of a piece of land can be obtained from an inspection of the crops or of the natural vegetation growing on it. It is also possible to form an idea of the level of fertility of a district or area from the general appearance of the countryside. Land that is hilly is often low in fertility, and an area with large flat fields, well grown hedges, healthy crops, and large trees can be generally recognized as good land.

Where pine trees grow in large numbers, the soil is usually light and dry and probably of low fertility or it would not have been used for forestry. Many plants denote the presence of too much water in the soil, including rushes, sedges, and buttercups. Certain weeds of arable land give an indication of soil type and condition. Coltsfoot is essentially a weed of heavy clay soils, whilst the presence of sorrel, spurrey, and mayweed is evidence that the land is short of lime. Charlock and poppies are found chiefly on light chalky soils, and fat hen is usually taken as an indication that the land is being well farmed, and therefore in a good state of fertility.

An inspection of the soil itself may give some clue to the level of fertility, particularly in the matter of colour. The amount of organic matter that a soil contains can be roughly estimated by the colour of the soil, and dark colour is usually an indication of high humus content. The depth of a soil affects its fertility ; and as a general rule, the deeper a soil, the more plant food there is available and consequently a greater capacity to yield. Thin and shallow soils, such as may be found on the chalk, or on the higher parts of hilly country, are invariably low in fertility.

Maintenance of Fertility

The most important factor in the maintenance of fertility is the supply of organic matter. Under the conditions of mixed farming that predominate in the British Isles, the problem of maintaining fertility is largely solved by the use of farmyard manure. The basis of this practice is the return to the land of plant residues in two ways. Firstly, animals do not digest the whole of the food they eat, and the indigestible residue is voided as fæces. Any surplus nitrogen that comes from the breakdown of the digested portion of the food is excreted in the urine. Secondly, when the animals are kept indoors, they are provided with bedding, the most useful material for this being straw, which is another plant residue. The fæces are mixed with the straw and the straw absorbs a good deal of the urine, and the mixture of excreta and

straw is ultimately made into farmyard manure. The mixture is taken from the houses or yards in which the animals have been kept and left for a time in a large heap. When the dung is first carted out from the yards, the straw is comparatively undecomposed and the farmyard manure is referred to as "long dung." After a period of storage in a heap, the straw decomposes to a dark brown material and farmyard manure is known as "short dung."

The benefits that arise from the use of farmyard manure are twofold. It provides a source of plant nutrients and, as it decays into humus, it has, like other forms of organic matter, an important effect on soil texture. From the point of view of plant nutrients, farmyard manure contains a percentage of the three important elements of nitrogen, phosphorus, and potassium, and may be regarded as a complete fertilizer. Some of the nitrogen and potassium are in a readily available form and have a fairly rapid effect on plant growth, whilst the remainder of the plant nutrients do not become available until the organic matter has been broken down by bacterial action. The fertilizing effect of farmyard manure is spread over a long period, and a dressing of farmyard manure not only benefits the crop to which it is applied, but its effect persists for at least one further year.

The double benefit derived from farmyard manure makes it almost impossible to give it a money value. In respect of plant nutrients it may be valued by comparison with the cost of these nutrients when purchased as fertilizers. But the composition of farmyard manure is not constant and the percentage of plant nutrients varies for a number of reasons. The quality of the dung depends upon the type of animals being kept. Fattening animals do not require large amounts of protein for flesh building or lime and phosphate for bone formation, and a higher percentage of these constituents is voided in the fæces. Young growing animals and milking cows utilize a higher proportion of these elements. This difference is minimized to some extent by the feeding of correctly balanced rations ; but in spite of this, the farmyard manure from fattening animals is generally richer in plant foods than that from other types of stock. Stable manure is rich in plant foods but dry in texture. For this reason, it ferments rapidly, and tends to lose nitrogen in the form of ammonia gas, which can often be detected in a stable by its smell. Dairy cows produce a manure that decomposes slowly, and is not so rich in plant nutrients. Cows produce a large amount of urine, but it is rarely possible to provide sufficient straw to absorb it. To make full use of the nitrogen and potash in the urine, it is advisable on a dairy farm to install a special tank to collect the liquid manure, which can be carted out and applied to the land.

The quality of the farmyard manure is also dependent upon the type of bedding material used. The important quality needed in a suitable bedding for livestock is the power of absorbing liquid. Wheat straw is the most absorbent bedding material grown on the farm and is capable of taking up sufficient urine and retaining sufficient fæces to produce about four tons of farmyard manure from one ton of straw. Peat moss is another form of litter that is used and is even more absorbent than wheat straw, but farmyard manure made with peat moss litter does not decompose very rapidly when applied to the land.

Probably the most important factor influencing the composition of farmyard manure is the method of making and storing. It is rarely advisable to apply farmyard manure to the land in the condition in which it leaves the cattle yards. The presence of unrotted straw in the soil encourages certain bacteria to work which lead to a decrease in the nitrate in the soil and a temporary loss of fertility. The general practice is to store farmyard manure for a period between taking it from the yards or sheds and applying it to the land. This process is known as the making of farmyard manure, and the principal change that takes place is due to bacterial action, which decomposes the straw into a brown and shapeless material. During the period of making, care should be taken to prevent any unnecessary loss of nitrogen that may arise from the fermenting and changing of a substance known as urea, a constituent of urine, into ammonia gas. This loss can be kept to a minimum if the heap is moist and contains sufficient straw to absorb the ammonia, and generous quantities of straw should be used for bedding purposes. In order to prevent fermentation taking place too rapidly, the heap should be made as solid as possible to keep out the air. The farmyard manure is often allowed to accumulate in the cattle yards all the winter, where it is kept solid by the treading of the animals and moist from their urine. When the manure is carted out of the yards and made into a heap, the carts are sometimes drawn over the top of the heap to give extra consolidation. Another potential loss of plant foods occurs when rain falls on the heap and washes them away. It may be a counsel of perfection to expect every heap of farmyard manure to be protected from the weather, but such a protection would undoubtedly reduce the losses of plant nutrients.

In farming practice, it is most convenient to apply farmyard manure to the land during autumn and winter, and the manure applied then was probably carted out from yards and made into a heap the previous spring. Thus, farmyard manure has to be carted twice and this adds considerably to its cost. When being applied to the land, the farmyard manure is deposited in heaps

over the field, spread on the surface of the land by hand, and buried when the land is ploughed. The interval between carting the manure on to the land and ploughing it in should be as short as possible to reduce the losses of nitrogen. Farmyard manure is usually applied to a root crop, especially to the cash root crops such as sugar beet and potatoes. The acreage of these crops that can be grown is often limited by the amount of straw available for making into farmyard manure. The average dressing of farmyard manure for a root crop is 12 loads an acre, which is approximately nine tons. To make this amount of farmyard manure requires two tons of straw, and this requires two acres of cereal crops, and every acre of root crops which receives a normal dressing of farmyard manure necessitates the growing of two acres of a cereal. On heavy land, where there are often no root crops, farmyard manure is commonly applied to beans or wheat.

The conditions under which farmyard manure may be made are so variable that it is impossible to give any standard figures for the amount of plant food it contains. Table 12 gives some typical figures for the analysis of an average sample of farmyard manure, together with the amounts of fertilizer that would be needed to provide equivalent amounts of nitrogen, phosphorus, and potash.

TABLE 12

COMPOSITION OF FARMYARD MANURE

PLANT NUTRIENT	PERCENTAGE	EQUIVALENT PER TON ON FERTILIZER	APPROX. VALUE OF FERTILIZER (1944)
			s. d.
Nitrogen ..	·7	$\frac{3}{4}$ cwt. Sulphate of Ammonia	7 0
Phosphorus ..	·25	$\frac{1}{3}$ cwt. Superphosphate ..	1 6
Potash ..	·5	$\frac{1}{4}$ cwt. Sulphate of Potash ..	3 3
Value per ton as represented by equivalent in fertilizers ..			11 9

It is important to note that farmyard manure contains only a small percentage of phosphorus, which is an indication of the amount of phosphorus retained by almost all types of animals so that less is excreted in the fæces. As a source of plant nutrient, farmyard manure may be valued at 11s. 9d. a ton, based on the cost of supplying its content of plant nutrients as purchased fertilizers. It is difficult to calculate the precise cost of making farmyard manure, but the two obvious items of cost are the value of the straw used for bedding, and the man and horse labour needed for carting. It requires one ton of straw to make four tons of farmyard manure, or 5 cwt. of straw for every ton of manure;

and, for a ton of manure, the straw alone, valued at the modest figure of £2 a ton, costs 10s. The manure has to be carted twice and, on the basis of 3s. 9d. a ton for each carting, the cost of carting amounts to 7s. 6d. a ton. This makes a total of 17s. 6d. a ton, a figure considerably higher than the value of farmyard manure as a source of plant nutrients. The difference in value, amounting, on the basis of these calculations to 5s. 9d. a ton, may be regarded as its value for the improvement of the physical texture of the soil. The cost of carting depends upon the distance the manure has to be carted, and as carting represents the major item of cost, the fields furthest away from the homestead are often neglected and the use of farmyard manure confined to the fields nearest the yards. In many cases, the outlying fields are more difficult of access and may not be served by a farm road and this gives another reason for their neglect.

Animals may contribute to fertility by the practice of allowing them to consume a crop on the land. This is known as folding and is most frequently done by sheep. They are used to consume such by-products as sugar beet tops, or to feed off a crop of swedes or turnips which has been specially grown for them. The effect of folding is to return to the land all the fæces and urine, representing the portion of the crop that cannot be utilized by the sheep. But no straw or other bedding material is used and the folding of animals does not lead to an increase of organic matter in the soil sufficient to affect the texture to any extent. The practice is confined to the lighter types of soil and adds to their level of fertility in respect of plant foods, and has also a beneficial effect in consolidating the land. The folding of sheep on arable crops is expensive in respect of labour for the continual moving of hurdles, but it may be less expensive than farmyard manure for the manuring of more distant fields on the farm, provided the soil is sufficiently light.

Apart from the use of livestock, the most important and most widely used method of adding to the organic matter of the soil is the growing of temporary leys, particularly where these include clover or some other leguminous fodder crop. In the Norfolk four-course rotation, the temporary ley or seeds crop comes once in every four years and occupies one year of the rotation. The usual mixture is red clover and ryegrass, which is undersown in the barley crop. It gives a crop of hay in June of the following year, and this plays a part in the maintenance of fertility by providing food for the stock used for making farmyard manure. After the hay crop has been removed, the clover and ryegrass continue to grow and produce a second crop, known as the aftermath. This may be consumed by sheep, or cut for hay or silage. When the

field is ploughed again for wheat, a considerable amount of organic matter is buried, and the residues from clover not only maintain but add to fertility because of the accumulation of nitrogen in the root nodules. It has been the practice for many years in the west and north of England to allow leys to remain for more than one year and to add still further to fertility by the greater accumulation of organic matter. There has recently been a great revival of interest in the use of longer leys, partly because of the greater yield of fodder than from permanent grassland and partly because of their effect on the building up of fertility.

In some cases, special methods of adding to the organic matter of the soil are used. Farmers near the sea coast are often able to obtain large quantities of seaweed, which is a very evident addition to the fertility of a farm. It is possible in some places to buy organic matter in the form of town refuse, or sewage material suitably treated, and for small market gardens grass cuttings and leaves are used. Fruit growers and market gardeners use large quantities of shoddy, which is a waste product from the woollen industry, and persists in the soil for a number of years.

The method adopted by a farmer to maintain the fertility of his land depends largely upon his system of farming. The practice of green manuring is most suitable for light soils, whilst the use of temporary leys, and the folding of forage crops, are associated in the main with some form of stock raising. For intensive arable farming, the use of farmyard manure is the most convenient method, as the by-products from arable cash crops provide both the food and the bedding for the stock.

Although the maintenance of fertility is associated primarily with organic matter, this alone may not be sufficient to maintain the level of fertility on a farm. The greatest potential loss of fertility on a farm is plant food in the form of nitrogen removed in the crops sold from the farm, washed away in the drainage water, and lost during the process of making and storing farmyard manure. These losses can be made good to some extent by growing leguminous crops and by the use of purchased feeding-stuffs, though this may be wasteful and extravagant. A simpler method of restoring losses of nitrogen is to use nitrogenous fertilizers ; and even in a soil with a high content of organic matter, these fertilizers are more rapid in action and promote a healthy growth of the crop, whilst the organic nitrogen is being made available by bacteria. The losses of phosphorus and potash may also be made good by the use of suitable fertilizers. The problem of the maintenance of fertility can be solved by a policy of keeping up organic matter in the soil, supplemented by the residues from purchased feeding-stuffs and the proper use of purchased fertilizers.

Chapter 5

THE USE OF FERTILIZERS AND LIME

THE object of the farmer is to maintain the fertility of the land, and to make it in every respect a satisfactory medium for the growth of farm crops. If a soil is to continue producing satisfactory crop yields, it must contain certain minimum amounts of available plant foods ; and of these, the three elements of critical importance are nitrogen, phosphorus, and potassium. If a soil is inherently deficient in any of these essential elements, plant growth suffers. It has been explained in the previous chapter that it is not always possible to make good soil deficiencies by the use of farmyard manure, by green manuring, or by the use of leguminous fodder crops. Elements of plant food have to be brought on to the farm, and the use of fertilizers is a simple method of doing this.

Fertilizer Requirements of Soils

The first reason for the use of fertilizers is to give the soil a supply of plant nutrients that it otherwise lacks. It is not easy to determine the exact needs of a soil for available plant foods, because every year a small proportion of the elements in the soil becomes available in a form in which the plant roots can absorb it. A chemical analysis using strong acids for extraction will reveal large quantities of potential plant foods, but no growing plant uses a strong acid for extraction. Thus the analysis indicates the reserve of fertility which may become available over a long period of time. The only means by which plant foods are extracted from the mineral content of a soil is the solvent power of the soil solution, and this is a weak solvent by comparison with the acids used for chemical analysis. It has been a problem of soil chemists for many years to devise a method of ascertaining the immediate fertility of a soil. The most common method in use is to extract the soil nutrients with a weak solution of citric acid, usually one per cent, which is comparable with the solvent power of soil solutions. The amounts extracted by such a weak solution give some indication of the amount of plant food likely to become available in the course of a growing season.

This is a guide to the content of available plant foods and assists in estimating the amount of fertilizer needed to make up deficiencies. But even with these figures, it is not possible to lay down any hard and fast rule as to the percentages of available plant foods that indicate a satisfactory level of fertility. Much depends

upon the type of crop, whether it is deep-rooted and draws food from the subsoil or is shallow-rooted and obtains food only from the surface soil. It also depends upon the general condition of the land, whether it is well drained and free from weeds.

The second reason for the use of fertilizers is to assist in the return to the soil of the elements of plant food removed by crops and stock and sold off the farm. These losses, together with those in the drainage water, must be replaced by some outside source of plant foods, either by purchased feeding-stuffs or purchased fertilizers. In this respect, fertilizers should be regarded as being supplementary to, rather than replacing, the use of organic matter for the restoration of fertility.

Nitrogenous Fertilizers

Nitrogen is probably the most important single element in plant nutrition, and plays a greater part in determining the yield of a crop than any other element. Its effect on the plant is to promote a vigorous growth of the vegetative parts, especially the stems and leaves, and the effect of an application of nitrogen to a crop is immediate and obvious, the leaves assuming a rich dark green colour. Crops grown for their roots and seeds need sufficient nitrogen to support the growth of stems and leaves, but nitrogen in excess of this requirement may lead to a loss in quality. Root crops become watery, whilst seed crops are late in maturing. In fodder plants, like kales or cabbages, that are grown for their leaves, large dressings may be used with no danger of a loss of quality. Care should always be taken not to use nitrogenous fertilizers to excess, for any nitrogen not used by the plants is lost in the drainage and, with all but fodder crops, there is a danger of loss of quality. A shortage of nitrogen is shown by stunted growth and plants of a sickly yellow colour.

The natural source of nitrogen in the soil is the organic matter, but the nitrogen it contains is not immediately available and has to be broken down by bacterial action until the nitrogen is in the form of a soluble salt, known as nitrate. This process of breaking down takes time, and a fertilizer with its nitrogen in the form of nitrates is immediately available for plant growth and has a very rapid effect.

There are three nitrogenous fertilizers commonly in use on the farm. Two of them, nitrate of soda and nitro-chalk, contain nitrogen in the form of nitrate, whilst the third, sulphate of ammonia, contains its nitrogen combined with hydrogen to give ammonia (NH_3); this must be broken down by bacterial action to nitrate before it can be used, and the effect is a little slower than that of the other two.

Nitrate of soda has been used as a nitrogenous fertilizer for more than a hundred years. It is found as a deposit in Chile, in South America, where it was probably laid down at the bottom of a lake that has since dried up. It is mined from this deposit and shipped to this country in bags. It is crystalline in form, readily soluble in water, but does not keep well, as it absorbs moisture and becomes unpleasant to handle. It is not often mixed with other fertilizers, but is used principally as a top-dressing for crops that need a rapid-acting application of nitrate. Because of its high solubility, it is almost invariably used on a growing crop. The residue from the fertilizer, after the nitrate has been used, is sodium, and this combines with the clay particles in the soil and causes a loss of lime. If the fertilizer is used too frequently on a clay soil that is deficient in lime, there is the danger of the formation of a sodium clay which is sticky when wet, and incapable of forming a tilth. Nitrate of soda contains about 15½ per cent of nitrogen.

Nitro-chalk is a manufactured product and has been on the market for a comparatively short time. It is made synthetically by the formation of a substance known as ammonium nitrate, and the nitrogen needed for the manufacturing process is taken from the atmosphere. Both parts of the substance contain nitrogen, the ammonium as NH_4 and the nitrate as NO_3, and both have a fertilizing effect. As a pure salt, ammonium nitrate absorbs a large quantity of water and the fertilizer cannot be stored in this condition, nor can it be used in a manure distributor. To overcome this property, the ammonium nitrate has been mixed with calcium carbonate, which makes it possible to put the fertilizer on to the market in a convenient granular condition. In this state, it will store well and is very easily applied, and the calcium it contains is also of benefit to the soil. It contains about 15½ per cent of nitrogen and 48 per cent of calcium carbonate, and is particularly valuable as a top dressing on soils that are slightly acid, and where the use of other fertilizers might lead to an increase in acidity.

Sulphate of ammonia is probably the most important and most extensively used nitrogenous fertilizer in the world. It was originally made as a by-product from the coal gas industry. In the making of gas from the heating of coal, a small amount of ammonia is driven off, which is removed from the gas by passing it through a solution of sulphuric acid. The ammonia is combined with the acid and is deposited as crystals of ammonium sulphate. The amount of sulphate of ammonia made in this way is not sufficient to meet the demand for it, and the fertilizer is now manufactured by a special process that makes use of atmospheric

nitrogen and combines it with hydrogen, which is present in water. The development of this process has assured an abundant supply of sulphate of ammonia, and the total supplies now available are sufficient to provide more than a half of the total requirements of nitrogenous fertilizer in the world.

Sulphate of ammonia is a greyish-white crystalline substance, and when dry is easily handled and applied. When stored for long periods it may set into a hard cake, but this is broken up without very great difficulty and is then quite easily applied. It contains about 20 per cent of nitrogen and is readily soluble in water. When applied to the soil, it is not washed out but its ammonium is absorbed by the clay in exchange for calcium, which combines with the sulphate of the fertilizer and is washed away in the drainage water. In time, the ammonium attached to the clay is acted on by bacteria and broken down into nitrate and absorbed by the plant. The result is that the clay has lost some of its lime content; and unless there is a reserve of lime in the soil to make good this loss, there is an increase in soil acidity. The continual use of sulphate of ammonia on a soil deficient in lime leads in time to soil acidity. The remedy for this is to maintain an adequate reserve of lime in the soil.

Sulphate of ammonia is frequently used as a top dressing for cereal crops in spring, and is often included in a mixture of fertilizers for any arable crop. It is delivered to the farm in bags and stores fairly well apart from the tendency to set into hard cakes. In no circumstances should sulphate of ammonia be mixed with any other fertilizer containing lime, as this results in a loss of ammonia as a gas.

The farmer may wish to compare these fertilizers with each other to calculate their relative cost. This is done by a system known as unit values and is worked out on the basis of the cost of each one per cent of nitrogen contained in the fertilizer related to its price per ton. All that is necessary is to divide the price per ton by the percentage of nitrogen. Assume that sulphate of ammonia costs £10 a ton, and contains 20 per cent of nitrogen, then the price per unit of nitrogen is £10 divided by 20, which equals 10s. a unit. Nitrate of soda may be sold at the same price, but as it contains only $15\frac{1}{2}$ per cent of nitrogen the cost per unit would be higher, being £10 divided by $15\frac{1}{2}$, which equals approximately 13s. a unit. Unless the farmer wishes to use nitrate of soda for a particular purpose, it is more economic to buy sulphate of ammonia. The value of any nitrogenous fertilizer can be calculated in this way and its unit price compared with that of sulphate of ammonia. A merchant is compelled by law to declare the percentage of nitrogen contained in a fertilizer offered for sale.

Phosphatic Fertilizers

Phosphorus is an element of great importance in the nutrition of both plants and animals, and many soils are deficient in it. In the nutrition of plants, phosphorus is associated with the development of the root system, with the earlier production of flowers, and with seed formation. Practically all farm crops respond to the use of phosphatic fertilizers, especially leguminous crops, roots, and cereals. In some ways, phosphorus may be regarded as a buffer against the effects of excess nitrogen, and an adequate supply of phosphorus ensures the maximum benefit from the applications of nitrogen. There is little danger from an excess of phosphorus except on very light and early soils, where rapid maturing is intensified and may result in poor yields. Phosphatic fertilizers are not washed out of the soil, and some of the phosphorus not utilized by the plant in one year is available for crops in succeeding years. It is thus possible to build up a reserve of phosphorus in the soil over a number of years.

The sale of crops and stock results in the loss of large amounts of phosphorus from the land, and the relatively low content of phosphorus in farmyard manure has been mentioned. The sale of animals involves a loss of the phosphorus contained in their bones, and milk is also high in phosphorus. One of the earliest forms of phosphatic manuring was the application to the land of crushed bones, which contain phosphorus combined with calcium. When applied in this form, the calcium phosphate is not soluble in water and there is no immediate response from the crop. There are still a number of phosphatic manures made from bones and sold as Bone Meal and Steamed Bone Flour, but they are used more by specialist market gardeners than by general farmers.

The most important development in the use of phosphatic fertilizers took place in 1842 when Sir John Lawes discovered that when bones were treated with sulphuric acid they were more rapid in action as a fertilizer. This process turned the calcium phosphate, as found in bones or in any other natural form, into a slightly different compound of calcium and phosphorus that dissolves in water and is more rapidly available for plant growth. This new form of phosphatic fertilizer was placed on the market under the name of superphosphate, and it is now one of the most important fertilizers in use, especially for arable farmers. As the plant food it contains is not washed out of the soil, it is usual to apply fairly heaving dressings to root crops, leaving a residue for the cereal crop that follows. Barley, or any other cereal crop undersown with weeds, is frequently given a dressing of superphosphate for the benefit of the cereal and the succeeding crop of clover.

Recently, a more concentrated form of superphosphate has been placed on the market under the name of Triple Superphosphate. As its name implies, it is nearly three times as concentrated as the ordinary type, and the amounts to be applied are about one-third of the normal dressings of superphosphate. Where it has been the practice to apply 6 cwt. of superphosphate, it is only necessary to apply about 2 cwt. of triple superphosphate. This represents a considerable saving in the quantity of the fertilizer to be transported and applied.

All superphosphates do not contain the same percentage of phosphorus, as they are made from a variety of raw materials. The phosphorus content of a fertilizer is expressed in terms of the chemical formula P_2O_5, a combination of phosphorus and oxygen. A merchant must declare the percentage of P_2O_5 in any manure that he sells. The various grades of superphosphates available contain 14 per cent, 16 per cent, and 18 per cent of P_2O_5.

Most of the superphosphate is made from a rock containing calcium phosphate, which is found as a natural deposit in some parts of the world, particularly in North Africa, Russia, the U.S.A. and some of the islands in the Pacific Ocean. It is quarried and imported to this country, and is sometimes used as a fertilizer with no treatment other than being ground into a fine condition. In this natural state, the calcium phosphate is insoluble in water, and unless it is finely ground it is a long time before it becomes available in the soil. When in finely ground condition, the phosphate is more readily dissolved by the soil water. The fertilizer is sold as Ground Mineral Phosphate, and has been found of special value on grassland in districts with a high rainfall, and particularly if the soil is slightly acid in reaction.

Basic slag is another phosphatic fertilizer widely used in this country. This is a by-product of the steel industry. When iron ore is mined, it contains a small percentage of phosphorus, which has to be removed in the making of steel. This is done by smelting the iron ore with limestone ; after the smelting, the phosphorus has been absorbed by the limestone and appears as a clinker. This contains both phosphorus and lime, but before it is used as a fertilizer it is ground to a very fine greyish-black powder. It is unpleasant material to handle, and can be applied only on a very still day. It has been found of particular value when used on grassland, and the combined effect of the lime and phosphorus has a most striking effect on wild white clover, which grows very freely after the use of slag.

There are various different processes in use for the smelting of iron ore, and the percentage of calcium phosphate in a sample of basic slag varies according to the process used. Basic slag is some-

times valued on the basis of its content of citric soluble phosphate, which is an indication of its rapidity of action, and slag must be ground so that at least 80 per cent of the powder will pass through a fine sieve with a hundred meshes to the inch, or ten thousand to a square inch. Some of the slags have a very high content of citric soluble phosphate and can be used for arable crops ; they are often applied to the seed bed or sown with the seed.

The different phosphatic fertilizers can be valued on the basis of the cost of each unit of P_2O_5. The method of calculation is the same as for nitrogenous fertilizers, and the percentage of P_2O_5 is divided into the cost per ton. The 1945 price of superphosphate containing 16 per cent of P_2O_5 is approximately £4 a ton, which gives a unit price of 5s.

Potassic Fertilizers

These are the fertilizers that supply the plant with potassium, which is usually referred to as potash, a combination of potassium and oxygen with a chemical formula of K_2O, the chemical expression for potassium being K. The effect of potash on plant growth is not so clearly defined as that of nitrogen and phosphorus, but it appears to have a generally invigorating effect on plants. It assists in the development of the leaves of a plant and makes them more efficient in the manufacture of carbohydrates. For this reason, an ample supply of potassium is of particular value to the crops grown for their high content of carbohydrate. Sugar beet and potatoes respond well to applications of potassic fertilizers, and do not grow satisfactorily on soils that are short of potash. Light sandy soils and peats are liable to be deficient in potash and are more likely to respond to dressings of potash than clay soils, which are normally well supplied with natural reserves of this plant food from the minerals they contain. The use of potassic fertilizers has grown much more necessary with an extension in the acreage of the cash crops like sugar beet and potatoes, which require large quantities of potash, and the amounts of farmyard manure have not been sufficient to give adequate dressings for these crops.

The most important source of potash fertilizers is in Stassfurt in Germany, where there are large natural deposits of potash salts. There are other deposits found in Poland, Palestine, Russia, Spain, and the U.S.A. The fertilizers are marketed as sulphate of potash and muriate of potash, or as a mixture of the salts as mined and sold under the name of Kainit and Potash Salts.

Sulphate of Potash contains 48 per cent of potash (K_2O) and is sold as a dry salt, which stores well, is easily applied, and mixes well with other fertilizers. It is valued very highly as a fertilizer

for crops where quality is of great importance, as, for example, with potatoes, fruit, hops, and market garden crops. Muriate of Potash as sold contains about 50 per cent of potash, and a pure sample may contain up to 60 per cent of potash. It often contains a small amount of common salt, which makes it less suitable for certain crops than the sulphate. Apart from this and the question of price, there is little to choose between them, and usually muriate is slightly the cheaper of the two for each unit of potash.

The mixtures of potash salts are not pure and contain a fairly high percentage of common salt; in some cases, salts of magnesium are present. The presence of common salt in the mixture gives these mixtures a special value for mangolds and sugar beet, which are both crops that have been derived from plants that originated near the sea, and which can derive some benefit from the salt. These mixtures are sold in standard grades containing fixed percentages of potash, and should always be purchased on the basis of the cost of a unit of potash. At 1945 prices, Sulphate of Potash costs about £13 a ton; and as it contains 48 per cent of K_2O, the price for each unit of K_2O is approximately 5s. 6d.

When potassic fertilizers are applied to the soil, they are not washed out, but the potassium is absorbed by the clay in exchange for lime, which combines with the sulphate or muriate and is washed away in the drainage water. All the potassic fertilizers are readily soluble in water and are quickly dissolved in the soil solution. Care must be taken to avoid heavy dressings of these fertilizers, as this would make a strong salt solution in the soil, which would tend to draw water out from the plant roots. This might be very serious in the case of young seedlings that have just germinated, and might cause them to die.

Organic Fertilizers

There are a number of substances of organic origin used as fertilizers. The most common substances are : guanos, formed from an accumulation of sea birds' excreta and imported to this country ; hoof and horn meal, and dried blood, which are waste products from slaughter-houses ; shoddy, a waste product from wool manufacture ; and fish manure. They are used principally as a source of nitrogen, but often contain appreciable amounts of phosphate as well. They can be valued by attaching the appropriate unit price for each plant nutrient, but they are invariably more expensive than buying the nutrients separately. This is due to the demand for them as fertilizers by specialist fruit growers and market gardeners. Because of their organic character, their plant foods become available much more slowly, and the effect on the crop is more gradual and sustained and is claimed to give

a better quality of produce. They increase the organic matter of the soil, and so help to solve one of the major problems of the specialist grower, which is how to maintain fertility in the absence of livestock for the production of farmyard manure. The high prices paid for these fertilizers tend to make them too expensive for use by the general farmer on the ordinary farm crops.

Compound Fertilizers

Farmers often wish to apply more than one plant nutrient to a crop. This may be done by mixing the required fertilizers together and applying the mixture, instead of applying individual fertilizers. The mixing may be done on the farm ; but to relieve the farmer of this work, manure merchants supply a mixture of fertilizers, often under the general name of compound fertilizers. The fertilizers are thoroughly mixed by machinery to ensure an even distribution of each ingredient. The mixture is supplied as finely ground material that does not cake or set into hard lumps. Compound fertilizers are a great convenience to farmers, provided that the cost of each ingredient is not much in excess of the price that would be paid for it as an individual fertilizer. Their cost can be estimated by using the unit values for nitrogen, phosphate, and potash when bought separately.

It is now a common practice for merchants to make up these mixtures to standard recipes for separate crops, and the fertilizers are sold as corn manure, sugar beet manure, or potato manure. These crop manures are made to include the plant nutrients that are normally required by that crop. A fertilizer for sugar beet and potatoes would probably contain a proportion of all three nutrients, whereas a fertilizer for application to a corn crop might contain nitrogen and phosphate only. The use of these crop manures may, in certain cases, result in a farmer applying plant nutrients to a soil that does not require them.

A more recent development has been the appearance on the market of certain highly concentrated fertilizers. The basis of most of these is the use of a compound containing both ammonia and phosphoric acid, and one constituent gives a supply of nitrogen and the other a supply of phosphate. These compounds leave no residues to affect the texture or lime content of the soil and there is a saving in bulk for transport and application. Many of the more important firms dealing in fertilizers market a complete range of concentrated fertilizers, in some cases designated by a series of numbers and in others by a series of letters. These fertilizers appear on the market in a very good physical condition and are often dry granular mixtures that are easily applied to the land.

They are very thoroughly mixed to ensure that each granule contains its correct proportion of the elements in the fertilizer.

The Application of Fertilizers

The usual method of applying fertilizers to the soil is by a machine known as a manure distributor. This can be set to deliver the correct amount needed for an acre of land. On smaller farms where there is no manure distributor, the fertilizer is broadcast by hand, though it is more difficult to get even distribution in this way. So far as possible, a calm day should be chosen for applying fertilizers. A high wind not only causes a loss of material, but makes the task somewhat unpleasant.

It is usual to apply compound fertilizers and phosphatic and potassic fertilizers to the land before the crop is sown. In some cases, they are first applied and then ploughed in, but more frequently they are worked into the seed bed. Fertilizers for potatoes are often placed in the bottoms of the ridges before the seed tubers are planted. Applications of nitrogenous manures are often given after the crop has started to grow. Cereals are frequently given a top dressing of nitrogenous fertilizer in the spring, especially if the crop is looking yellow after a cold and wet winter. Root crops are sometimes given a supplementary application of fertilizer after the crop has germinated and has been hoed and singled.

A recent development has been to drill the fertilizers close to the seeds. This practice is based on the theory that young growing plants derive greater benefit from the fertilizer being close at hand than from the same amount of fertilizer spread evenly throughout the soil. There is, however, a danger that a concentration of soluble fertilizers near a germinating seed will draw off its water and affect both germination and growth. To achieve this proximity of seeds and fertilizers, the two are drilled by the same machine, known as a combine drill. In some cases the seed and fertilizer are delivered through the same spout, and in others they are delivered separately. There is as yet no final opinion as to the theory and practice of this combination, and more investigation of the problem is needed.

Rates of Application

It is impossible to give any fixed rules for the amount of fertilizer that should be applied to any particular crop, as the quantity needed varies according to circumstances. In general, applications of nitrogenous fertilizer should not exceed 3 cwt. an acre, with the possible exception of green fodder crops such as kale, which might receive up to 4 cwt. an acre. The dressings of super-

phosphate are frequently higher and may be as high as 6 cwt. an acre ; whilst with basic slag on grassland, 10 cwt. an acre can be used. With potassic fertilizers, it is uncommon to give dressings equivalent to more than 2 cwt. an acre of muriate of potash. The most satisfactory plan is for the farmer to get an analysis of his soil and to work out a system of cropping and a scheme of manuring to go with it. The greatest problem in the use of fertilizers is the maintenance of the phosphate and potash, large amounts of which are sold from the farm.

In general, it is probably true to say that farmers in this country do not make the fullest use of fertilizers. Larger applications would often lead to better yields and greater profits. But there is a limiting factor which has an important bearing on the quantity of fertilizer that should be used. The application of 1 cwt. of fertilizer will give a certain extra yield, but it does not follow that the use of 2 cwt. would double the extra yield. In fact, each additional cwt. applied gives a smaller extra yield until a point is reached when an application of an extra cwt. of fertilizer gives no extra yield at all. This is illustrated in the figures given in Table 13, which shows that a dressing of approximately 2 cwt. of sulphate of ammonia gave an extra yield of 10·3 bushels. When 6 cwt. were applied, as compared with 4 cwt., the additional 2 cwt. of fertilizer resulted in an increase of only 1·9 bushels. It can be concluded from this table that the economic limit of using nitrogenous fertilizer was reached by using 4 cwt. an acre, and that further expenditure on fertilizer would be wasted and give the farmer no return. This is one of the economic laws that affect farming and is known as the Law of Diminishing Returns.

TABLE 13

RETURNS FROM USE OF INCREASING AMOUNTS OF NITROGENOUS FERTILIZERS

AMOUNT OF FERTILIZER	YIELD BUSHELS PER ACRE	INCREASE YIELD FOR EACH 2 CWT. FERTILIZER
No Nitrogenous Fertilizer	18·3	—
2 cwt. Sulphate of Ammonia (containing 43 lb. nitrogen)	28·6	10·3
4 cwt. Sulphate of Ammonia (containing 86 lb. nitrogen)	37·1	8·5
6 cwt. Sulphate of Ammonia (containing 129 lb. nitrogen)	39·0	1·9
8 cwt. Sulphate of Ammonia (containing 172 lb. nitrogen)	39·5	0·5

Liming

There are a number of different forms in which a farmer can supply calcium to the soil. Calcium carbonate occurs naturally as limestone or as chalk but these differ in texture, one being hard and crystalline and the other soft and crumbly. They are ground into a fine condition and applied to the soil in that form. In some districts the chalk is naturally soft, and lumps of chalk spread on the land break down to a fine powder by the action of frost during the winter months. It is a common practice in some parts of the Eastern Counties to apply dressings of from 5 to 10 tons of lump chalk to the acre.

If chalk or limestone is burnt in a kiln, carbon dioxide representing nearly half its weight is driven off and calcium oxide, or quicklime, is left. As no calcium is lost in the burning this quicklime is a more concentrated source of calcium than the original chalk or limestone, and smaller dressings can be used. Quicklime is caustic, apt to burn the skin of those handling it, and is more unpleasant to handle than ground limestone. When exposed to water, quicklime absorbs the water and changes to slaked lime, which is powdery in texture and easily distributed.

The choice between one source of calcium and another is largely determined by local circumstances. It depends on the proximity of natural supplies of limestone or chalk, and the presence in the neighbourhood of the necessary grinding machinery or of the kilns required to burn the limestone to quicklime. In some districts near the coast, sea sand with a high percentage of calcium compounds in the form of shells is applied to the land. There are a number of forms of lime wastes used on the land, such as the lime sludge from sugar beet factories where quicklime is used in the extraction of the sugar from the beet. Owing to its high water content, it is usually only practicable to use lime sludge on farms within easy reach of the factory. The basis of comparison between one form of "lime" and another is the price per unit of calcium oxide, and unusual forms of "lime" should be valued in relation to the more common forms, full allowance being made for extra costs of transport that occur, as with wet lime sludge.

Apart from the determinations made in a laboratory, it is possible to recognize the need for liming in the field, though not to calculate the amount of lime required. Clay soils short of calcium are invariably sticky and lacking in crumb structure, and a number of weeds are often associated with acid soils. Two common weeds that are an almost certain indication of lack of calcium are spurrey and sorrel. Fields of barley and sugar beet with a number of patches where the crop has failed often prove on further investigation to be acid in reaction. Acidity on grassland leads to the

formation of a thick unrotted mat of organic matter on the surface. These observations may be confirmed in the field by the use of certain indicators, which change colour if liming is necessary, though field observations should be confirmed by a more careful analysis in the laboratory.

The application of calcium compounds should not be left until the soil has become acid in reaction ; and if a soil is naturally deficient in calcium, it should receive regular applications at a fixed point in the rotation. It is important to realize that liming is not a permanent improvement, because of the continuous losses of calcium from the soil that have to be made good. The usual practice is to lime the soil during the winter and to work the material into the soil when the cultivations are being done for the spring crops.

Chapter 6

CULTIVATION OF THE SOIL

THE various operations carried out on the soil from time to time are known generally as cultivations. They are necessary for a number of reasons. Most important of all, the soil must be brought into a condition favourable for the germination of seeds and for the subsequent development of the crop. A second object of cultivations is the elimination of weeds that compete with the crop for water and plant nutrients. The soil needs cultivations to retain its tilth, and for aeration in heavy soils, and water conservation in light soils. So far as possible, the objects of cultivations should be to provide favourable conditions for plant growth without endangering the soil. If cultivations are carried out at the wrong time, or when the soil is in an unsuitable condition, more harm than good will result. There is probably no branch of farming in which the skill and judgment of the farmer is of the same supreme importance as in the timing of cultivations. It is more of an art than a science, because not only do soils vary from one farm to another, but weather conditions are rarely the same from one year to another.

Seed Bed Preparation

To get the soil into a condition suitable for the sowing of seed is known as the preparation of a seed bed. In order to encourage germination, the soil must contain both air and moisture, and the soil particles must be in fine condition so that the delicate roots that appear after germination can keep in contact with the soil and not dry out for lack of moisture. The requirements of a seed bed vary to some extent with the type of crop and with the time of year at which it is being prepared. As a general rule, small seeds require a fine seed bed, whilst larger seeds germinate satisfactorily in a much rougher seed bed. The difference in size between clover seed and beans is considerable, and a seed bed suitable for beans would be too coarse and rough for the small seeds of clover. Some crops require a deeper seed bed than others. Cereal crops are usually sown on a fairly shallow seed bed; whereas for sugar beet and potatoes, great depth is required, and often the subsoil as well as the top soil is cultivated.

Spring and autumn are the two main seasons for the sowing of farm crops. Seed beds prepared in the autumn should not be as fine in texture as spring seed beds because the action of the weather during the winter reduces any clods to a fine tilth. If the seed

bed is too fine at the beginning of winter, it becomes sticky and pasty by the following spring. On spring seed beds, there is no possibility of subsequent weathering down, and any clods present dry out and remain in that condition for most of the growing season. The general rules for seed beds are that the smaller seeds require a fine seed bed, spring seed beds should be fine, and autumn seed beds left with a certain amount of clod. The presence of clod offers a considerable amount of protection for the young plants against the winter frost.

There is no standard procedure for the formation of a seed bed, as conditions vary according to the type of soil, the weather conditions, and the crop that occupied the land previously. Basically, there are three major forms of cultivation needed to make a seed bed. The land must first be ploughed, then worked with a cultivator or a heavy harrow, and finally broken down by harrowing. The times at which these various operations are carried out and the number of times they have to be done vary almost from farm to farm, if not from field to field, and are always subject to the weather conditions of the season when they are being performed.

Ploughing is the first stage in the preparation of a seed bed under almost all conditions. The effect of ploughing is to invert the top six to nine inches of the soil, to bury any stubble or weeds or farmyard manure that may be on the surface, and to expose a fresh surface to the air. The ploughing can be done in a number of different ways by using a different form of plough. The furrow slice can be laid almost flat by being broken as it is turned over, or it can be set at an angle. When a seed bed has to be prepared in a short time, particularly in the spring, the flat broken furrow slice is used to give the greatest degree of consolidation, with no spaces between the furrow slice and the bottom of the furrow, and the broken surface assists in getting a tilth. When the furrow slice is set at an angle, it exposes the maximum amount of surface to the action of the weather and is used when land is ploughed in autumn and winter.

The action of the weather is probably of as much importance in the preparation of a seed bed as tillage operations, and the farmer can save a considerable number of cultivations by taking advantage of the effect of weather on soil. When the furrow slice is turned over, the soil is usually in a firm close state, and may even be wet and sticky. When it is in that condition, no further cultivations can be done on it until the furrow slice has been allowed to dry and then to crumble. Crumbling is caused by the various changes brought about by the weather. As the furrow slice dries, the outside particles flake away, and, with alternate wetting and drying, the whole slice gradually breaks down. This happens

more rapidly during a period of frost. When the soil freezes, the water it contains turns to ice and expands, and when the thaw comes, the furrow slices disintegrate. This breaking down by the action of the weather makes the subsequent operations more easily carried out.

Weathering is of great importance in the cultivation of heavy soil with a large amount of clay in it. When a soil of this type is ploughed, the furrow slices are often almost livery in character, but the changes that take place in them after exposure to the weather are most remarkable. Clay is very susceptible to the wetting and drying action of the weather, and to the effect of frost. Great care must be taken in the cultivation of clay soils, and considerable damage is done by cultivating a clay soil when it is not in the right condition. From the account of the properties of clay that has been given in an earlier chapter, it will be appreciated that clay cannot be cultivated when it is wet and plastic, or when it is dry and has set into hard clods. Between these two extremes, there is a point when the clay can be worked to produce the necessary crumb structure. Crumb structure in clay is greatly assisted by the presence of lime and organic matter, but care must be taken to carry out cultivations at the right time. There are two possible times when a clay soil can be worked to advantage. One is when the clay is drying out, and has passed the stage when it is apt to paste but has not dried sufficiently to form a clod. The other time is the reverse position, when a clay soil is passing from the dry cloddy stage after a shower of rain. Of the two, the second condition is the safer and is likely to give better results.

In order that the soil may derive the maximum benefit from the action of the weather, the interval between ploughing and the next cultivation should be as long as possible. A long interval is not always practicable when seed beds have to be prepared in the spring, especially after a root crop that is being folded, so that the land is not vacant until quite late. The amount of cultivation needed after ploughing depends upon the interval between ploughing and the next operation, and upon the weather conditions during that period. For an autumn seed bed, with an interval of about six weeks after ploughing, and suitable weather conditions, it may only be necessary to use a heavy harrow to get enough tilth for drilling to begin. For the finer seed beds required in the spring, it is preferable to do the ploughing during the winter, and the amount of cultivation needed to complete the seed bed then depends upon weather conditions. The later cultivations reduce the soil to a fine condition and the harrow completes the final breaking down. At the same time, the use of the harrow consolidates the ground. The roll is sometimes used to assist in

making a seed bed in the spring, and has the effect of crushing the small surface clods and increasing the fineness of the seed bed. If there are many large clods on the surface, rolling is of limited value, as it tends to press the clods into the soil without breaking them up.

After the seed has been drilled, the soil is harrowed with a light harrow, partly to cover the seed effectively and partly to give further consolidation. After drilling small seeds on a spring seed bed, harrowing is often followed by rolling, to ensure that when the seeds germinate the soil is packed tightly around them and the roots are able to establish themselves with little danger of drying out.

When a deep seed bed is required, as for sugar beet and potatoes, cultivations are often carried out on the subsoil. Depth of seed bed is sometimes obtained by ploughing deeply and bringing some of the subsoil to the surface. When this is done, there is the danger that the valuable top soil containing organic matter and bacteria is buried; and unless sufficient fertilizers are applied to give a supply of plant food, the crop may be a failure. The subsoil may also be broken up by attaching a special fitting to the plough, which penetrates the subsoil at the bottom of the furrow and loosens it without bringing it to the surface. Another method is to use a second plough, which follows in the furrow behind the ordinary plough and breaks up the subsoil. This loosening of the subsoil facilitates the penetration of roots to a good depth and is an insurance that the crop does not suffer unduly from drought as the plant roots are in contact with the water at the lower levels of the soil.

Land that has been ploughed to the same depth for many years may develop a plough pan at the bottom of the furrow. This is caused by the weight of the plough passing along and consolidating the soil at the same depth. When this happens, plant roots do not penetrate into the subsoil and the plants may die during a drought because they are shallow-rooted. A plough pan also impedes the natural drainage of the soil. When a plough pan has been formed, it should be broken up by using a subsoiler of some kind.

The number and type of cultivations carried out on a soil depend mainly upon the texture of the soil. The terms "light" and "heavy" are applied to soils, not because of their weight in relation to their volume, but because they offer light or heavy resistance to the implements used on them. In the days when horses were the main source of power on the farm, it needed two horses to pull a plough through a light soil, whereas heavy clay land needed four horses, and such land was often referred to as "four-

horse" land. The texture of the soil affects not only the amount of power to be used, but the number of days in the year when the soil is in a fit state to be cultivated. The characteristic of light soils is their ability to allow water to pass rapidly through them, and cultivations may begin much sooner after rain on light soils than on heavy soils. This is reflected in the numbers of days' work obtained from the horses on the farm. On a heavy land farm, an average of 180 days' work a year is a likely figure, whilst on a light land farm the number may rise to 220. Consequently, the cost of a day's work from a horse on a light land farm is less than on a heavy land farm, because it is possible to get a greater number of working days for approximately the same cost. One of the advantages of using tractors on a heavy land farm is that the work is done more rapidly and full use made of the opportunities when the heavy soil is in a fit condition to be cultivated.

Control of Weeds

After the preparation of the seed bed, the next important object of cultivations is the control of weeds. A weed has been described as a plant out of place, and the problem of weed control is of great importance. The most serious effect of weeds on crop growth is their competition for water and plant nutrients, and the overcrowding that results from a large number of weeds means an absence of air and sunlight for the crop. As a rule, weeds grow more rapidly than crops, and small seedlings may be smothered by excessive weeds. Another trouble caused by weeds is at harvest time, and a cereal crop that is full of weeds takes much longer to dry sufficiently for the crop to be carted because of the green weeds in the sheaves. With a potato crop it is difficult to use a spinner satisfactorily if there are many weeds present, as they clog the machine. Weeds may affect the selling value of a crop, as happens when a sample of wheat contains seeds of wild onion, which taint the flavour and make the wheat unsuitable for human consumption. The damage caused by weeds is of such importance that every effort must be made to keep them under control. It is one indication of good farming when the land is clean and free from weeds.

From a farmer's point of view, weeds of arable land fall into two main types, annuals and perennials. Annual weeds not only compete with, and possibly smother, a crop, but shed a very large number of seeds if allowed to survive. These cause a still further infestation of the land, and there is an old farming proverb that says, "One year's seeding means seven year's weeding." Every effort should be made to prevent annual weeds from setting seed. Perennial weeds survive from one year to the next and gradually

spread, and as they usually produce new plants from a piece of root or stem left in the soil, they are destroyed only when completely removed from the soil.

The general principle underlying the control of weeds is to attack them at a stage of their growth when they are most vulnerable. With annual weeds, the weakest stage is just after germination and before the plants have had sufficient time to establish themselves. Perennials are most vulnerable when the ground is dry and when, by moving the soil, the underground root or stem is dried out. These conditions are found mostly during summer or early autumn, or possibly in some districts during early spring. As the two types of weeds differ widely, different methods of control are needed.

There are a number of occasions when the opportunity can be taken to kill weeds. They may be destroyed by the cultivations carried out in the course of preparing a seed bed. With crops that are sown in wide rows, cultivations are carried out in the rows whilst the crop is growing. Another method of control is to cultivate the land between the harvesting of one crop and the sowing of another. On some types of land, particularly heavy clays, it may be necessary to keep the land free of a crop for a whole year, when all the cultivations are directed towards the destruction of weeds. This is known as a bare fallow.

During the preparation of a seed bed, a number of both annual and perennial weeds are destroyed, particularly after a cereal crop. Little or no intercultivation can be done on a cereal crop, and after harvest the surface of the stubble is often covered with a large number of seeds from annual weeds that have flowered and set their seed before the corn was ready for harvesting. If the stubble is ploughed immediately after harvest, the weed seeds are buried, and are brought to the surface at a later ploughing. After an interval of a few weeks, and especially if there has been some rain, a considerable number of the seeds on the stubble have germinated, and if ploughed in at this stage are destroyed. In order to encourage the seeds to germinate, it is a common practice to carry out a shallow cultivation on the surface of the stubble, using a broadshare or a cultivator. This operation forms a kind of seed bed in which a large proportion of seeds germinate. When the land is ploughed a few weeks later they are buried and killed. This operation is often known as stubble cleaning and is one effective method of controlling annual weeds. One drawback is that a number of annual weeds do not germinate under these conditions. Slender foxtail, or black grass, is a serious annual weed that cannot be destroyed in this way because it does not germinate until the middle of November. As most autumn-sown cereals

have been drilled and have germinated by this time, the weeds cannot be killed. This weed is very common on heavy land on which crops are frequently sown in the autumn, and one method of controlling it is to grow an occasional spring-sown crop and to destroy the black grass during the winter. This example shows the importance of understanding the different characteristics of weeds and attacking them accordingly.

When the land has been ploughed and the young seedling annuals buried, the subsequent cultivations, particularly the harrowings, bring the roots and stems of perennial weeds to the surface, when they are collected and burnt. With a spring-sown crop, there is a further opportunity of clearing perennial weeds by harrowing, and any annuals that have germinated during the winter or early spring are also destroyed. This method of controlling perennial weeds during the preparation of a seed bed is most effective on the lighter types of soil. With an autumn-sown cereal, a large number of annuals germinate during the winter and early spring, and these are destroyed by harrowing the crop in the spring. Some annual weeds, for example, poppies, often do not germinate until spring corn has been sown, and are killed by a light harrowing of the crop.

The most important crops that allow of intercultivation are the root crops, which are grown in rows at least 18 inches apart. Root crops play an important part in the destruction of weeds and are often referred to as "cleaning" crops. As soon as the separate rows of the crop can be distinguished, a horse hoe is used between the rows, and at this stage most of the annuals are in a comparatively weak condition and easily destroyed. Most root crops require singling; and as this operation is often combined with a thorough hand-hoeing, it is probably the most effective method of killing weeds. Root crops may be horse-hoed two or three times before the crop reaches the stage when the leaves touch and prevent further cultivations. If the root crop grows well, the foliage becomes very thick and smothers any weeds that have survived the earlier cultivations.

Root crops are not grown extensively on heavy land because of the difficulties of preparing a good seed bed on this type of land in the spring, and the danger of puddling the land when harvesting the crop in the autumn. Moreover, the necessary intercultivations are more difficult to carry out on a heavy soil when it has dried during the summer, and the use of roots as a "cleaning" crop on heavy land is not possible to the same extent as on light land. Beans are a heavy land crop, sown in wide rows, and may be intercultivated the following spring. Beans act as a cleaning crop, though not as effectively as a root crop. The practice of

growing arable silage on heavy land also contributes to the control of weeds. The crop, usually a mixture of oats, beans, and vetches, is sown in wide rows in the autumn and can be intercultivated in spring and early summer. By June the crop develops a dense mass of foliage which completely covers the soil and smothers the weeds. Silage crops are harvested by the middle of July and as the next crop is not sown until the autumn, the farmer has an opportunity of two months of summer to carry out a short summer fallow, or, as it is sometimes called, a bastard fallow. The growing of silage, combined with regular stubble cleaning, is an important method in the control of weeds on heavy arable land.

The traditional method of cleaning heavy arable land is the use of a bare fallow. To carry this out, the land is kept free of a crop for a whole year, and as there is no crop to be sold, a bare fallow means a loss of income as well as the expense of making the fallow. The procedure is almost the opposite of the operations carried out to prepare a seed bed. The land is usually left as a stubble from the previous harvest until the following spring. It is then ploughed, preferably when wet, and a second ploughing follows soon after, the plough being taken across the furrows of the first ploughing. This cuts up the soil into large square clods which dry out as the summer progresses, and any perennial weeds they contain die for lack of moisture. The bare fallow is essentially an operation directed against perennial weeds, as few annual weeds germinate in the conditions that have been provided. During the summer, a number of cultivations are carried out on the fallowed land, usually with the object of turning the clods to complete their drying. A successful bare fallow is possible only during a reasonably dry summer, and by September, when rain should have fallen, it becomes possible to break the clods down to form a seed bed for an autumn-sown cereal.

The summer, or bastard, fallow is a modification of the bare fallow and has the additional advantage that the value of a year's crop is not lost. A summer fallow may be taken in July after a silage crop, or after a seeds ley, the land being broken up immediately after harvesting a hay crop in June. One danger that arises from the use of fallows is an attack of wheat bulb fly on a subsequent wheat crop. This insect lays its eggs on bare ground during the first fortnight of August, and when the land is lying fallow at this time of the year an attack of wheat bulb fly is almost certain to follow. As a means of preventing the insect from laying its eggs, a catch crop of mustard is often drilled at the end of July, allowed to grow and cover the land during the critical period, and then ploughed back into the land to serve as a green manure.

Some specially serious weeds may have to be removed from the land by hand, particularly when they are growing in a corn crop. Thistles and docks are two dangerous perennial weeds because, in addition to persisting themselves, they flower and produce a heavy crop of seed. To prevent this happening, it is often necessary to remove them by hand, the docks being pulled out completely and the thistles spudded with a special tool. This is expensive, and labour may not be available to do it, but it is a very effective method of destroying the weeds.

Whilst discussing the subject of weed control, mention should be made of the modern method of spraying weeds, which is not a cultivation but is being used on an increasing scale. The method consists of spraying the weeds with a chemical substance that scorches the leaves of the plants and causes them to die. It is specially effective when used in the spring against annual weeds that have germinated, and have developed a number of leaves in the form of a rosette, which lies more or less flat on the surface of the soil. Sprays are most frequently used in cereal crops, and little or no damage is done to the young corn plants because their leaves are smooth and upright and do not retain more than a small amount of the spray. Charlock is a serious annual weed on many types of land ; when in the rosette stage, it is easily destroyed by spraying. One common substance used for spraying weeds is sulphuric acid, and a 10 per cent solution is effective against most annuals. A number of other spraying materials are being developed which are less dangerous than sulphuric acid to the men handling them. This method of control cannot be used when a cereal crop has been undersown with seeds, as the material used for spraying kills the small clover plants.

Other Effects of Tillages

The cultivations carried out in the preparation of seed beds have a number of important, though indirect, effects on the soil. In the case of clay soils, the texture of the soil is improved if the cultivations are done at the right time, or spoiled if the soil is cultivated when in an unsuitable condition. The use of cultivations for the improvement of texture is, in the main, the exposure of a large area of the soil to the action of the weather. Clay soils may become badly puddled and very sticky after a wet harvest, especially of a root crop, and the only way of restoring the texture of the soil is by ploughing it and allowing the weather to produce the desirable crumb structure once more. Cultivations have the effect of allowing air to enter the soil. This is of particular importance in a clay soil, which, because of its close texture, is liable to be badly aerated. An improvement in the aeration of a clay soil not

only assists in the removal of water but encourages plants growing in it to develop a better rooting system. Bacterial action is dependent upon a supply of air and also benefits from the effects of cultivation.

On the lighter types of soil, there is not the same need for aeration by means of cultivations. These soils are naturally well aerated and water drains easily through them, and one problem is the conservation of moisture. This is of particular importance on light soils in an area with a dry climate. The critical period in the cultivation of light soils in a dry climate is the spring, when excessive cultivations may cause the soil to dry out, and seed may not germinate through lack of moisture. Land that has been put into ridges for potato planting is liable to lose moisture, and land should not be left in this state for longer than is necessary. The best method of preventing an undue loss of moisture from a light soil is to plough the land during the winter and to confine the cultivations in the spring to surface tillages. The roll is sometimes used with the intention of conserving moisture by consolidating the land so that water can be drawn from the lower levels of the soil, but it is doubtful whether this has more than a limited use, as the action of the roll has little or no effect below the first two or three inches of the soil.

The cultivation of the soil is the oldest activity of the farmer, yet, no branch of farming is at present so imperfectly understood. Science has not discovered the precise effect of cultivations on the soil, and there is at present a conflict of opinion whether or not the farmer should reduce the number of his cultivations. Much research and investigation is needed on this subject, and for the present, and possibly for many years, cultivation of the soil will remain an art that can be fully learned only by experience. Experience of cultivating one type of soil for many years may be no guide to the methods that should be followed on another soil, and the great diversity of soil types adds to the difficulties of obtaining a full knowledge and understanding of the subtle problems of soil cultivation.

CHAPTER 7

CONTROL OF PLANT PESTS AND DISEASES

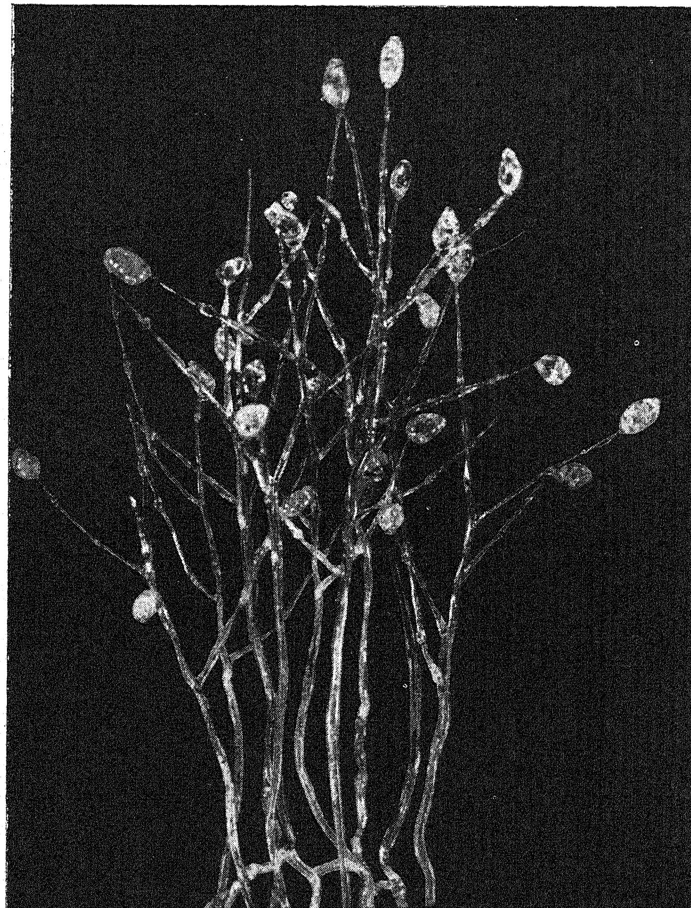
ONE of the risks that farmers have to face is that their crops may be attacked by pests and diseases. The term "pest" is used to cover all forms of insect life that depend on crop plants for their food and constitute a hindrance to the proper development of plants. Some insects attack the leaves of plants, and, by extracting food materials from them, cause them to cease their normal function of manufacturing carbohydrates and other plant foods, and this results in a reduction of yield. Other forms of insect life exist in the soil and live on the roots and lower parts of the stems of young growing plants, and if they attack the farmer's crop may destroy a large proportion of the plants.

FUNGUS DISEASES

Diseases of plants are caused mainly by different forms of fungi that invade the roots, stems, leaves, and flowers of plants. A fungus is a primitive type of plant life which has no leaves and no chlorophyll and is therefore dependent on other plant material for its existence. Some fungi live on dead organic matter, whilst others survive only if they attach themselves to a living plant. The fungi belonging to this latter group are the chief cause of disease on crop plants. Although they are a type of plant life, many fungi that cause disease are very small structures and their true shape and form cannot be seen except under a microscope. When magnified in this way, many fungi that appear to the unaided eye as moulds, mildews, rusts, and black powders, are very beautiful in shape, as can be seen in Fig. 16. A fungus may attach itself to the leaves of a plant and penetrate into its tissues, thus reducing the capacity of the leaves for photosynthesis and resulting in a lower yield from the crop. Other fungi persist in the soil and may attack the roots of a plant, or the base of the stem near the surface of the soil. There are certain diseases known as stem rots that develop a weakness in the straw of cereals and cause the crop to lodge. In some cases, the spores, or some resting stage of the fungus, may be attached to the grain of a crop and lower its market value. For example, bunt, or covered smut of wheat, so called because of its sooty appearance, may be present in wheat, making it quite unsuitable for milling into flour. The presence of a fungus disease on a root crop may ruin its keeping quality. This happens when potato tubers are infected with blight, which causes them to rot in the clamp.

PRACTICAL MEASURES AGAINST PESTS AND DISEASES

The subject of plant pests and diseases is vast, and a detailed treatment is beyond the scope of a work of this nature. Every pest



(*Model and photo by Dr. Dillon Weston*)

FIG. 16. LARGE-SCALE MODEL IN GLASS OF THE FUNGUS RESPONSIBLE FOR POTATO BLIGHT

and every disease has a different, and often complicated, life cycle, and the methods of control that have been worked out are based upon a knowledge of their life history. It is not proposed to describe in detail the many pests and diseases of importance to the farmer but to give an account of the various practical methods

used for their control and of the application of the different methods to some of the more common plant diseases.

There are a number of ways in which a farmer can influence the susceptibility of his crops to attacks by fungi and insects. The use of an excessive amount of nitrogenous fertilizer on a crop leads to the development of a mass of luxuriant but somewhat sappy foliage, and cereal crops over-manured in this way are very liable to attacks of mildew or rust. Similarly, a crop that is not growing satisfactorily appears to offer less resistance to the attacks of insect pests. The preparation of a good firm seed bed encourages rapid germination and early growth so that the crop is more likely to withstand such an attack. Early sowing leads to earlier development and also encourages a high degree of resistance. Oats that are sown late are often unable to survive an attack of frit fly, a small insect the larva of which burrows its way into the growing plant, whereas an early sown crop is more vigorous and is much less seriously affected when attacked. Kale is very liable to attack by the turnip flea beetle, a small black insect that extracts the sap from the young leaves and is recognized by its habit of jumping from the plant when disturbed. A critical time for an attack of this insect is at the end of April or early in May, and an early sowing of kale should produce plants that are, by this time, large enough to withstand the attack, whilst a crop of late sown kale may be completely destroyed and have to be sown a second time.

One of the most serious insect pests that attack farm crops is the wireworm, a small creature about half an inch in length which lives on the roots of living plants. It is particularly prevalent in grassland and may cause serious damage to crops taken on a newly ploughed grass field. One method of reducing damage done to a crop is the preparation of a good seed bed with adequate consolidation, and a supply of fertilizer, particularly phosphate, to encourage speedy germination and early growth. The risk of loss on a field suspected of being highly infested with wireworm can be reduced by growing a crop that is less susceptible to attack. Beans, peas, and flax grow successfully in spite of the presence of wireworms where, under the same conditions, a cereal crop might be seriously damaged, if not destroyed. The cultivation of land provides an opportunity for birds to collect many of the insects and grubs that might attack a crop. Some diseases flourish on land that is deficient in lime, an example being club root disease, a primitive type of fungus that causes swellings on the roots of cabbages and turnips, and which is much reduced by the application of lime. Other diseases are due to a deficiency of some plant nutrient. Heart-rot in sugar beet develops on land that is short

of boron and can be cured by applying boron, in the form of borax, to the soil.

Diseases caused by Unbalanced Cropping

The effects of many plant pests and diseases can be reduced by a proper balance of cropping and the use of a good rotation of crops. Many agents causing disease are present in the soil and survive only when the crops they attack are grown too frequently on the same land. One especially serious pest that is encouraged by repeated growing of the same crop is the eelworm. There are different species of eelworm but they do not all attack the same crops. There are two species of great importance, one of which attacks potatoes and the other sugar beet. The potato eelworm does not attack sugar beet, but the sugar beet eelworm, while it does not attack potatoes, causes damage to a variety of crops including mangolds and the cruciferous crops.

Eelworms remain dormant in the soil during winter in the form of eggs contained in a small lemon-shaped cyst, which is rather smaller than the head of a pin and is brown in colour. In the spring, some of the eggs hatch and the young eelworms, which are small and almost invisible without a magnifying glass, escape into the soil and attack the roots of any host that may be growing. The eelworms penetrate and kill the small rootlets and the plant forms new rootlets, which in a bad attack are also killed by the eelworms. The growth of the plant is stunted and the leaves develop an unhealthy appearance. Towards the end of summer, the female worms form more cysts containing eggs, and most of them are left behind in the soil when the crop is lifted. The growing of a susceptible crop leads to an increase in the number of eelworms in the soil and the likelihood of a more serious attack on a susceptible crop the following year. The only method of control is the use of suitable crop rotations. On land known to be free of eelworm, a susceptible crop should be grown only once in three years, to prevent any infestation, and on land mildly infested the interval should be increased to four years. On land that is badly infested, susceptible crops should not be grown for at least five years, during which time many of the eelworms die for lack of a suitable host plant.

Land may become infested with eelworms in a number of ways. They are unable to travel more than a short distance of their own accord and their spread is mainly brought about by the cysts getting into the soil by artificial means. The cysts may be introduced in the soil attaching to seed potatoes or on the roots of plants for transplanting. The infestation may spread from field to field in soil on the boots of workmen or attached to wheels of

carts or tractors. Eelworms are a serious pest once the land has been infested and care should be taken first to prevent infestation and secondly to avoid growing a susceptible crop too frequently on the same land. As one means of preventing the spread of sugar beet eelworm, there is a clause in the contract drawn up between the sugar beet factory and the farmer that the sugar beet shall not be grown on a field that had a crop of beet or any other susceptible crop in the previous year. Potato eelworm is often prevalent on allotments where potatoes have been grown intensively on the same piece of land for a number of years.

Unbalanced cropping may also increase the liability of attack by certain fungus diseases. This occurs with a fungus disease of wheat known as "whiteheads" or "take-all," which causes a large number of empty heads of grain. The fungus persists in the soil and survives only if wheat or other susceptible crops, such as barley or certain grasses, are grown too frequently. Clover rot is another fungus disease that lives in the soil. When red clover is grown too frequently on the same land, it is liable to fail because of attacks of this fungus. Beans belong to the same botanical family as the clovers and appear to be attacked by the same disease. The best method of preventing attacks of clover rot is an interval of five or six years between crops of red clover. On land known to be infected, longer intervals up to twelve years are advised and red clover should not be sown under wheat following a bean crop.

Airborne Diseases

Many fungus diseases come from the spores of the disease that are blown about in the air and, alighting on the leaves of a plant, penetrate the leaf tissues. One method of reducing the effects of diseases spread in this manner is to grow varieties of crops that are for various reasons highly resistant, if not completely immune, to the diseases. Resistance may be due to the leaves having an unusually tough outer layer of cells, which prevents the fungus from entering the leaves. The development of resistant varieties of crops has been the work of the plant breeder, and there are varieties of wheat that are completely resistant to attacks of a common disease known as yellow rust. This is found on the leaves and stems of the plants as a yellow powder. Attempts are constantly being made by plant breeders to produce varieties of crops that are resistant to the more serious diseases, and it may yet be possible to produce cereals that are immune to mildew, or potato varieties that are not susceptible to attacks of potato blight. One serious potato disease present in some districts is the wart disease, so called because of the warty growths that develop on the tubers. But there are varieties that are immune to the disease

and can be grown safely in contaminated soil. By law, only immune varieties of potato may be grown on wart infested land, in order to reduce to a minimum any possibility of the disease spreading.

Seed-borne Diseases

One means by which fungus diseases spread is on the seed of a crop, and this occurs with a number of diseases that attack cereals. By various means, spores of the disease become attached to the seed corn, but the spores are minute and cannot be detected by inspection except under a microscope. When the seed is planted, the spores germinate and attack the growing crop. There is a very reliable method of controlling these seed-borne diseases. The seed is treated before sowing with a powder containing a chemical, usually some form of organo-mercury compound, that is poisonous to the spores and destroys them when they begin to germinate after the seed is sown. Such powders, or dressings as they are sometimes called, are known as seed disinfectants. The dressing of seed is effective against such diseases as leaf stripe of oats and barley, and bunt of wheat. It should be the standard practice of every farmer to dress the seed of all cereal crops as a precaution against these various diseases, which all lead to a reduction in yield. The dressing of seed corn is not a difficult operation and, following the instructions given with any reliable seed dressing, it can be done in a disused churn converted for the purpose, or in one of the special seed dressing machines that can be purchased. Many seed merchants are in a position to supply seed corn that is dressed and ready for sowing. As the seed dressings are poisonous, care must be taken by the workmen using them, and surplus seed corn that has been treated must not be fed to livestock.

Destruction of Wild Host Plants

Some of the important pests and diseases that attack crop plants spend a part of their life cycle on other plants. With insect pests this often occurs in winter, when the insect is in a resting stage, and the plants that act as hosts during this period are frequently weeds and other wild plants or bushes. If these plants can be discovered and destroyed, it assists in the control of the disease. A famous example of control by this method is that of the black rust of wheat, which was found to spend a part of its life cycle on the wild barberry. The destruction of the barberry bushes led to a considerable reduction in the incidence of the disease. In this country, it has been found that the different forms of aphids, or black flies, which attack sugar beet, beans, and members of the cabbage family, migrate for the winter to various wild shrubs, one of the commonest host shrubs being Euonymus or spindle tree.

The attacks of aphids on these crops would be reduced if these various shrubs were destroyed. The carrot fly lives largely in the hedgerow weeds and plants, and, if the hedges and ditches surrounding a field of carrots are cleared of vegetation, the severity of attack from carrot fly is reduced. With many biennial crops, such as brussels sprouts and sugar beet, a number of plants may be kept growing through the winter for the production of seed the following spring. These plants may harbour certain pests and diseases that spread to the ordinary crop the next year. It is a wise precaution to keep the plants grown for seed as far as possible from the fields where the normal crop is growing, so as to minimize the possibilities of any disease spreading from one to the other. Every effort should be made to destroy possible sources of infection from which an attack of disease may originate. When a potato clamp has been emptied, any tubers that have been discarded should be collected and destroyed in case they are infected with potato blight from which a fresh attack may develop.

Spraying and Dusting

Even if a farmer has taken all the precautions possible to reduce attack from pests and diseases, some of his crops may become infected. When this occurs, a more direct form of control may be adopted by using a spray or dust to kill the infecting organism. In general, the use of sprays and dusts for destroying insects and fungi is not practicable to the same extent with the ordinary farm crops as with the more specialized crops such as fruit and hops. One of the common diseases of farm crops that is controlled by spraying is Potato Blight. This is a fungus disease that attacks the leaves of the potato and causes them to turn black and die. The spores travel by the agency of wind and rain and are much more likely to spread in warm and moist weather conditions. To prevent the disease from attacking the plant, the leaves are sprayed with Bordeaux mixture, made by mixing copper sulphate, or blue stone, and lime. This deposits a thin coating on the leaves, and when the spores settle on the leaves they are destroyed. Another method is to use a copper powder dust, which can be applied more easily and is more convenient for use where there is a difficulty in the carting of water. The first spraying should be carried out before the plants meet in the rows, and a second spraying about three weeks later. If the leaves become infected with the disease, spores from the leaves drop on to the soil and infect the tubers and cause them to rot in the clamp.

Methods are being developed for the use of dusts and sprays against a number of insect pests that attack farm crops. Two of the most serious pests are turnip flea beetle, which attacks most

crops of the cabbage family, and an aphis which attacks sugar beet. These pests can, to some extent, be destroyed by a dust applied by a special machine and a good control of the disease is obtained. The problem of spraying farm crops is largely a matter of expense in relation to the value of the crop. The growers of fruit and hops carry out a regular routine of spraying to control the many diseases that attack these crops, but the income from an acre of these crops is much higher than from farm crops, and the grower can afford a considerable expenditure on the control of disease. Another form of direct attack on plant pests is the use of poison baits. Bran, mixed with Paris green, an arsenic preparation and very poisonous, is used as a bait to destroy leather-jackets and cutworms, which eat young sugar beet plants. The bait is strewn along the rows and eaten by the insects, thus killing them.

Virus Diseases

There is another group of plant diseases that attack a number of farm crops and are of special importance with potatoes. They are known as virus diseases, and are due to an infective principle which is difficult to isolate and cannot be seen even with the most powerful ordinary microscope. When virus enters the sap of a living plant, it causes certain markings and even deformities, and an infection by a virus usually results in an unhealthy plant. Some viruses have a more severe effect on the plant and destroy the plant in a very short time.

The potato is susceptible to a number of different virus diseases, and one source of infection is brought about by the agency of aphids, or greenflies. These insects carry the virus in their system; and when they puncture the leaves of a potato plant, the virus enters the sap and the whole plant becomes infected. The presence of some of the different diseases can be detected by a number of external symptoms. The leaves of the plant develop a mottled appearance from one virus, and curl and crinkle due to another, and the plant as a whole exhibits an unhealthy appearance. From an economic point of view, the most serious aspect of virus diseases is their effect on yield, which is very low from a badly infected crop. The aphids causing the infection are especially prevalent in warm and dry districts, and almost every potato crop grown in these conditions is certain to receive an infection. The diseases become intensified in a crop grown from "seed" potatoes of a crop that has been previously infected; and if tubers from the badly infected crop are used again for seed, the resulting crop grows so badly as to give little or no yield.

A practical method of reducing the effects of virus diseases on the yield of a crop is to use, as seed, potato tubers that are free

from the diseases. In the cool and exposed parts of Great Britain, particularly in areas with a high prevailing wind, there are considerably fewer aphids, and, as a result, potato plants grown in these districts receive little or no infection. These conditions are found in parts of Scotland and Ireland, and in the more exposed areas in the West of England and Wales. When seed potatoes from these districts are planted, they produce a far superior yield, and many growers of potatoes plant only seed tubers that have been grown in an area free from virus diseases. A crop grown from Scotch or Irish seed potatoes is not seriously infected by viruses, and seed from this crop is often planted again under the name of "once grown" seed. After a second year, the infection becomes too severe for further use, and fresh seed should be purchased. The seed potato trade is of great importance to areas in which virus-free seed can be grown, and care is taken by official inspection of crops being grown for seed to ensure that any plant showing symptoms of a virus disease is removed and destroyed.

Advice on Plant Diseases

While it is essential that farmers should appreciate the importance of disease control, it is unlikely that many of them possess the expert knowledge to recognize the different pests and diseases that attack their crops, or to decide how the disease can be controlled. There is provision made in the form of a specialist advisory service* for information and assistance on this important subject, and farmers should not hesitate to consult the advisers both on the general subject of controlling disease by good methods of farming and on the action to be taken to deal with an outbreak of a particular disease. In this way farmers benefit from the new methods of control that are constantly being discovered by scientific research workers. It is impossible to make an estimate of the loss of crop caused every year by insect pests and fungus diseases, but it must be substantial, and it should be the aim of every farmer to produce crops free from disease and consequently more profitable.

* Details of this service can be obtained from the Agricultural Organizer for the County or from the Ministry of Agriculture.

Chapter 8

CONSERVATION AND STORAGE OF FARM CROPS

ONLY a small proportion of farm crops are consumed as they are growing. Grass is one crop regularly consumed in this way, and some root crops are folded by sheep, but most farm crops have to be harvested. Crops for sale must be harvested, and may have to be stored before they are marketed. Feeding-crops are also harvested and, as crops grow during a part of the year only, winter food for livestock has to be provided by the conservation and storage of crops grown during the summer months. Different methods are needed according to the type of crop, and the cultivation and growing of a crop must be followed by a satisfactory method of harvesting.

Harvesting is a term usually associated with cereal crops, but it must not be forgotten that all crops need harvesting and that the time of the year for the bringing in of crops varies. The first crops ready for harvesting are the various green fodders grown for the purpose of being made into hay, and hay-making begins in early June, and in some districts may continue into July. Arable crops grown for making into silage are cut and carted in the middle of July, and by the end of July the first cereal crops are ready to cut. Corn harvest may last until September, and the potato crop must then be lifted and put into clamps. The lifting of sugar beet begins in October and continues throughout November and December. Mangolds must be lifted by the middle of November and put into clamps, whilst kale and other similar crops are harvested gradually, a small quantity being cut each day and taken to the stock. On light land arable farms, some of the root crops are consumed by folded sheep during the winter and may not be cleared until February or March. Thus for about nine months in the year there is a harvesting operation of some kind being done on one farm or another.

Haymaking

The first crops to be harvested are the green fodders grown for hay. These crops, of which grass may be considered the most important, are the natural food of most types of farm livestock, and are eaten in their fresh green state during spring and summer. But if they are to be used as winter food for livestock, they must be preserved in some manner. The oldest and most common method of preserving green fodders is to make them into hay, and many crops can be preserved in this way. Hay can be made from

a permanent pasture, from a temporary seeds ley, and from fodder crops such as lucerne, sainfoin, and vetches. The principle underlying the making of hay is to cut the crop when it is green and allow it to dry sufficiently to be put into a stack, with no danger of heating or the formation of moulds. A crop preserved in this way in a stack will, if properly protected from the weather, be suitable for feeding to animals two or three years after being made.

A crop to be made into hay is allowed to grow through the spring and early summer without being cultivated in any way or grazed by stock. Most of the plants used for hay grow rapidly during May and begin to develop a flowering stalk by the end of May or early in June. At this point, the crop has nearly reached its maximum weight per acre, but it has not matured sufficiently to contain an undue amount of fibre. The flowering stage is the best time at which to cut a crop for hay. If the cutting is left until the plants have ceased flowering and started to form seed, there is little increase in total weight, but the plants become more fibrous. Much of the hay made by farmers in this country is probably not the valuable fodder it might be because it has been cut too late and contains a high proportion of dried grass stalks with little more feeding value than straw. It is preferable to err on the side of cutting too early rather than too late, as the higher feeding value of an early crop will more than compensate for any loss of weight in the crop. Hay-making is a process that differs in detail from one part of the country to another, but the principles are the same. When a crop is cut for hay, the green material contains from 75 to 80 per cent of moisture, and before it is ready for carting the moisture content must be reduced to about 20 per cent. The crop is cut by a mower and left on the field in rows or swaths, and these are left until the herbage on top has dried. The swaths can then be turned over by a machine to allow the herbage underneath to dry, but in some districts the hay is tossed in the air by a tedder to increase the speed of drying. In most parts of the country, hay is collected into heaps or cocks when it is about half made, and allowed to complete its drying gradually. This assists in the retention of a green colour in the hay; and if a spell of bad weather should intervene, hay in cocks does not suffer any serious damage. The hay is ready for carting and being made into a stack when it contains about 20 per cent of moisture; if it is carted with a higher moisture content, considerable fermentation is set up in the stack, leading to heating and a possible danger of fire.

The three agencies that bring about the drying of the grass are the sun, the air, and fermentation in the grass itself, often referred to by farmers as sweating. The sun is a powerful drying agency

and too much sunshine will bleach the crop, causing it to lose some of its feeding value and making the leaves dry and brittle so that they break off and are lost. Even in the finest weather, hay should not be turned too frequently to hasten the process of drying; for though the crop may be ready for carting very quickly, the hay is not of the best quality and is very brittle and lacking in colour. The drying effect of air is more gradual and results in better quality hay. The air has more effect on drying if the crop is spread evenly over the field instead of being left in rows, but there is the danger of damage from rain. The sun and air remove most of the moisture in a very short time, if weather conditions are favourable, but the final moisture is best driven out of the plant by fermentation. This final drying process is begun when the hay is made into cocks, and completed when it is finally stacked. Some degree of heating in the stack gives a pleasant flavour to the hay, and by the time the hay is used for feeding, the moisture content has fallen to 14 per cent.

The quality of hay depends to some extent upon the type of grass or fodder plant used. The leaves of grass have a higher feeding value than the stems, and grass with a high percentage of leaf, which is often determined by early cutting, will yield a better quality hay. The amount of leaf depends partly upon the strains of grass in the sward and partly upon the weather conditions. In dry seasons, the absence of moisture tends to promote earlier flowering, and the production of stems at the expense of leaves. If the sward contains a proportion of clover, the feeding value of the hay is increased. The hay from red clover, lucerne, and sainfoin is coarser and more fibrous than meadow hay ; and if cutting is delayed, these plants develop very woody stems, which are low in feeding value.

The losses that may occur in the making of hay have a great effect on quality, and bad haymaking may spoil an otherwise good crop. The two important ways in which losses may occur are the leaching out of the food materials by rain and the breaking off of leafy material that has been dried too rapidly and become brittle. The loss by leaching may be unavoidable because of untimely rain, but if the crop is quickly made into cocks these losses can be reduced to a minimum. The danger of losing brittle leaves can be avoided to some extent by handling the crop as little as possible. The leaves of red clover, lucerne, and sainfoin become very brittle when dry, and these crops need careful handling to avoid leaving the most valuable part of the crop on the field. A third potential source of loss is the making of the hay into a stack before it is ready. This sets up excessive fermentation, and, even if the stack does not heat sufficiently to cause a

fire, overheating may reduce the feeding value of hay by as much as 30 per cent.

As a means of preserving fodder crops, haymaking is not very efficient ; even when hay is made under ideal conditions, the loss in feeding value between the fresh crop and the hay made from it may amount to 40 per cent. It is, however, the traditional method of preserving grass for winter food and has the advantage of simplicity and requires little in the way of special equipment. Recent improvements in the machinery used for haymaking have meant a saving in labour and a shorter period between cutting and stacking, which results in a better quality product.

Grass Drying

The comparative inefficiency of haymaking has led to investigations into other methods of preserving green fodders for winter use. One form of preservation is that of drying the crop artificially to drive off the surplus moisture. There have been some developments in this process for the preservation of grass; instead of allowing the grass to reach the flowering stage, it is cut earlier in its growth, when it has a higher feeding value. Young dried grass is equal in feeding value to many of the concentrated cattle cakes that can be bought. A special machine has to be installed to effect the drying, and there are a number of designs available. In principle, they all consist of some form of furnace which produces a current of hot air that drives the moisture from the fresh grass.

The installation of a grass-drying machine involves a considerable capital outlay, and there must be a sufficient acreage of grass to ensure economic working. The grass must be cut while it is short ; in this condition it is not easily collected for loading into carts, and the amount taken in one cartload is small. A further difficulty is to ensure a uniform supply of grass for drying. Grass drying can be carried out from May to September, but during that time there may be some periods when there is more grass than the machine can deal with, and others when there is not sufficient to keep the machine working. The critical factor in grass drying is the proportion of water to be removed from the green material. Under average conditions, every ton of dried grass requires the removal of four tons of water, but in wet seasons the amount of water to be driven off may be as much as seven tons. As a method of preservation, it is very efficient, the losses in feeding value being of the order of 10 per cent ; and where conditions are suitable, it produces a highly nutritious feeding stuff. It is as yet in its early stages and further developments may be expected that will lead to its adoption on a much wider scale

than at present, though it will probably be economic only on larger farms. Dried grass is usually stored in bales, and it can also be ground into a meal and kept in bags. It is unlikely that a protein-rich food such as dried grass will completely replace haymaking, because of the need of all ruminant animals for a proportion of roughage in their diet.

Silage Making

Another method of preserving green fodders for winter use is to make them into silage. To do this, the crop material is cut and carted while still green and put into a silo or pit, or made into a stack, and compressed as much as possible to exclude air. The plant material immediately begins to ferment, partly due to the continued respiration of the cells, and this is accompanied by a rise in temperature. The amount of heat produced depends upon the amount of air present ; and as the silage at this stage is losing some of its feeding value, heating should be kept to a minimum by the exclusion of air. The initial rise in temperature ceases when the cells of the plant are dead, and a new process begins when certain micro-organisms present in the material start to feed on the carbohydrates in the herbage and produce an acid called lactic acid. This is the substance that is formed when milk goes sour. The production of lactic acid continues until the whole mass of material contains sufficient acid to kill the bacteria, and the acid then acts as a preservative and prevents any further decomposition. After reaching this stage, the material will keep in good condition for many months.

The best quality silage is made when the formation of lactic acid takes place rapidly ; if this does not happen, other acids are formed which give the silage an unpleasant smell, particularly when butyric acid, the acid of rancid butter, is present. The action of the bacteria forming lactic acid is dependent upon the amount of carbohydrate present, and with some immature crops there is not sufficient carbohydrate available to ensure speedy fermentation. It has been found that the formation of lactic acid is more rapid if an additional amount of readily available carbohydrate is added when the crop is put into the silo. One method of doing this is to spray the herbage with a solution of molasses and water. Molasses is a by-product of the sugar industry, and the carbohydrate it contains is rapidly utilized by bacteria. The solution is sprayed on the different layers of herbage material, and the contents of the silo must be firmly compressed, to shorten the period of respiration and speed up the bacterial action. The use of molasses in silage making has resulted in the production of silage of much higher quality, and a better control of the final

product is obtained. Another method used to minimize the amount of fermentation is to add a solution of acid to the material. By this addition the acidity of the mass is quickly brought to the stage that prohibits any undesirable fermentations that would result in the formation of butyric or other unpleasant acids. This method is not as simple for use on the farm as that of adding molasses.

There are many designs of silo for use on the farm. They may be permanent structures made of wood or concrete ; if they are more than 20 feet in height, they require a machine to chaff the green material and a fan to blow it up through a flue to drop down into the silo. There are a number of portable silos available, which are usually made up from sections of wood or concrete, and can be erected at different places on the farm as required. A still more portable type of silo can be made by using a stout wire frame lined with thick waterproof brown paper. Silage can be made by digging a pit in the ground, filling it with material, and weighing it down with earth. Because of the difficulties of drainage, it is not always possible to rely on good quality silage from a pit. Another method of making silage is in a stack ; but owing to the problem of excluding air from a stack, there is often a heavy wastage of material from the top and sides of the stack.

Almost any green fodder crop can be successfully made into silage. A mixture of oats, beans, and tares is often grown on heavy land for the specific purpose of silage making. This mixture gives a high yield of produce from an acre and the inclusion of two leguminous crops ensures a good percentage of protein. Silage can also be made from most forms of clovers and grasses ; and in practice, it is most convenient to take a hay crop in June, and to use the aftermath for silage. Sugar beet tops are sometimes made into silage, but as the tops have the crown of the root attached, it is difficult to compress them as firmly as required, and the tops often have an excessive amount of dirt attaching to them. Kale was for long considered unsuitable for the making of silage, but with molasses excellent silage can be made from it.

Silage provides a succulent winter feed for livestock, and the losses in feeding value in the process of making silage are considerably less than with haymaking. As a food, it is generally palatable to stock, and, if properly made, silage retains a high proportion of carotene, which is needed in winter rations to maintain the rich yellow colour of milk and butter. As a form of preservation, it has a great advantage over haymaking because it is virtually independent of weather conditions, though the use of green material with too much water may produce a somewhat acid type of silage. As a food, it does not replace hay completely,

but should be considered as a supplementary form of preservation, to be used for any surplus green fodders that become available. Silage is ready for feeding as soon as 10 days after it has been made, and in this way it differs from hay, which needs a much longer period to mature. Silage can be fed without further preparation, whereas roots have to be sliced or pulped before feeding to cattle in yards. The making of silage was greatly encouraged during the period of the second world war, because of the valuable contribution it makes to the problem of providing home-grown foods for livestock.

Storage of Root Crops

Except in the more northerly part of Great Britain, root crops are generally consumed on the field or lifted and fed as required. But mangolds cannot be left on the field, because they are not hardy against frost, and they have to be lifted before there is any danger of serious frosts. They are stored in a clamp, which is shaped like a pyramid, and typical measurements for a mangold clamp are a base of 9ft. with an apex of 6 ft. The roots must be lifted carefully to avoid any bruising, and the leaves are cut off without cutting any part of the root. If the root of a mangold is cut it will 'bleed' and lose a considerable amount of food value, and will not keep. The clamp is covered with a layer of straw about 8 in. in depth to allow for the running off of the water and to provide aeration. After an interval to allow for 'sweating,' the straw is covered with a layer of 8 in. of earth, which acts as a protection against frost. As the mangolds are still alive, they continue to respire, and provision must be made for ventilation. This is done by leaving wisps of straw protruding at intervals along the top of the clamp. When the mangolds are first clamped, they contain certain immature substances that cause scouring if the mangolds are fed to stock. Mangolds should be allowed to mature in the clamp until the end of December before being fed. When clamped satisfactorily, mangolds will keep for many months and can be used for feeding to stock until the following June.

Potatoes are not hardy against frost and, unless the crop can be sold immediately on lifting, the tubers have to be stored in clamps similar to those used for mangolds, though smaller in size. Typical dimensions for a potato clamp are a base of 6 ft. and an apex of 4 ft. The clamps are protected from frost by a layer of straw covered with earth, and the clamp is not opened until the potatoes are to be sent to market. Before marketing, the tubers have to be sorted to separate small and seed-sized potatoes from the ware potatoes sold for human consumption. This is done on a machine known as a riddle, which has a series of wire sieves to separate one size of tuber from another. The storage of potatoes

uses a considerable quantity of wheat straw and the potatoes from an acre of land giving a yield of 8 tons require the straw from two-thirds of an acre of wheat. By contrast with potatoes, the other important cash root crop, sugar beet, is not stored on the farm but is lifted and dispatched to the factory, and the harvest is spread over the months of October, November, and December.

The Harvesting of Cereals

The grain is the important part of the cereal crops and harvesting is dependent upon the ripening of the grain. The stage at which the different cereals are ready for cutting varies. Wheat is cut when the grain is 'cheesy' in texture and is allowed to mature in the stook, whilst barley must be allowed to ripen completely before being cut. With oats, the usual practice is to cut the crop when in a comparatively green stage, as this helps to prevent undue loss of grain through shedding. Oat straw is in itself a valuable fodder, and any food materials not transferred to the grain in the process of ripening are utilized by stock when the straw is used for fodder. A proportion of the cereal crops may be threshed from the stook, but the main bulk is usually carted and made into a stack and threshed later in the winter. It is important that the sheaves of corn should be dry before they are stacked, as heating in the stack damages the grain and causes a loss of feeding value. The stack must be constructed with sheaves higher in the centre than at the outside to prevent rain soaking in ; and when completed ,the stack should be thatched to protect the corn from the weather. When the farm has a Dutch barn, the need for thatching does not arise.

After threshing, it may be necessary to store the grain for some time. If the grain should be damp, there is a danger of heating when it is stored up in a large heap, and damp grain may also become musty and covered with moulds. The problem of grain storage arises when a combine harvester is used, and grain threshed in this way has, in most cases, to be dried before it can be stored. In general, apart from the grain harvested by a combine harvester, the problem of grain storage is not a serious one for the British farmer, as threshing is done through the winter, and the amount of grain threshed can be adjusted to the speed at which it can be sold or used on the farm. Precautions must also be taken when storing grain against damage from vermin, and in some cases damage can be caused by grain weevils, though this is more a problem of storing grain on a large scale rather than on a farm.

Chapter 9

CROP IMPROVEMENT

FROM the days when man first began to cultivate the soil for the growth of plants, there has been a steady and continuous improvement in the quality and yield from crop plants, and many crops have been improved to such an extent that their modern forms bear little or no resemblance to their wild ancestors. Cereals were the first farm crops to have been brought into cultivation, and wheat in particular appears to have been grown from time immemorial.

Improvement by Selection

In the course of centuries, the cereals have been gradually improved by the simple process of selecting the ears of the best plants for use as seed. Early writers on agriculture laid great stress on the importance of care in the selection of seed corn, and advised farmers to select their seed from the biggest plants and to use seed from the districts with the kind of climate that would lead to proper ripening. Improvements brought about in this way were slow and gradual, and it was not until about a hundred years ago that the selection of plants for seed production became in any way systematic. Progress in the improvement of cereals became more rapid when a number of people began selecting individual plants bearing ears of corn of exceptional size or quality. The grains from these ears were sown separately and multiplied until sufficient was available for sowing as a crop. Many of the more important cereal varieties grown during the nineteenth century were introduced in this way and were developed from the grain of a single ear.

This method of improvement is still practised to some extent, but the chances of getting a better variety depend on the appearance of a plant with some unusual features that distinguish it from the others. For the most part, the offspring of plants resemble the parent plant, but occasionally a very different plant is produced and, if this is separated and multiplied, it retains the characters that first distinguished it. The appearance of these unusual plants has been explained by the scientist as a sudden but permanent change in the constitution of the plant due to various unknown factors; and when a new form of a plant develops in this way, the change is called a "mutation," a word derived from the Latin word meaning "a change." It is important to distinguish between the sudden and permanent changes such as mutations,

and the temporary changes in a plant that may be due to its being grown in especially favourable or unfavourable conditions. Thus a crop of barley might, under adverse conditions, give a yield composed mainly of very small grain, but if these are grown under better conditions the small grains would yield a crop of normal-sized grains. Similarly, a crop grown using only large grains as seed gives a mixture of large, medium, and small grains, and a crop from small seed will give a similar range of size. Continual selection of the largest grain does not lead to any increase in the average weight of grain produced. When a crop variety has been developed to this stage of purity, it is referred to as having been "fixed," or as being a "pure line."

The fact that most cereals are self-fertile makes it relatively simple to fix a type that has been developed from the selection of a single ear. Rye is a cereal that is normally cross-fertilized by pollen from another rye plant, and mass instead of single plant selection is used. In order to improve this crop by the method of selection, a large number of plants of similar character are taken and grown in isolation so that pollination is effected only between plants of similar type. One effect of cross-pollination is to increase the chances of a deterioration in the crop when grown under ordinary farm conditions for a number of years, because of the inter-crossing of good and bad types.

Application of Mendelism

At the beginning of the present century, a new and more certain method of crop improvement became possible by the process of scientific plant breeding. Some work had been done on the crossing of one type with another in an attempt to combine in one plant certain desirable features of the parent plants. Thus a high-yielding variety of wheat with a weak straw might be crossed with another variety giving a poor yield but having a short stiff straw in the hope of combining in the offspring a plant with a high yield and a strong straw. The results of these crosses had been generally unsuccessful, and it was largely a matter of chance whether a better variety resulted. The failure in the work of the earlier plant breeders was due to the lack of knowledge of the way in which the characters of parent plants were inherited in the offspring. In 1901 there was published in this country a translation of the results of a series of experiments carried out, some thirty years earlier, by an Austrian monk named Mendel, which had been published in a local Journal and had received little or no attention at the time. The experiments were carried out with peas and showed that the characters of parent plants were transmitted to their offspring according to a definite plan and in fixed

proportions.* With this knowledge the plant breeder was able to predict what proportion of the offspring resulting from the crossing of two parent plants should have the desired combination of characters.

The application of this knowledge to plant breeding has resulted in the production of many new varieties of plants that have proved of great value to the farmer. In the case of the wheat crop, all the original British varieties were far inferior to imported wheat in respect of baking quality. By the systematic crossing of British wheats with those of foreign origin, varieties are now available that will grow well under British conditions and yield a flour equal in baking quality to that obtained from foreign wheat. Two outstanding varieties in this respect are Yeoman and Holdfast, both of which are the results of plant breeding and are now widely grown by farmers in this country. It has been found that resistance to disease is a character transmitted according to Mendel's principles and this has enabled varieties to be produced that are resistant to specific diseases. The work of the plant breeder has produced new varieties of barley such as Spratt Archer and Plumage Archer with an improved yield and a better malting quality, and new varieties of oats combining resistance to frost and high feeding value have been introduced.

Testing of New Varieties

The two modern methods of improving cereal crops are the production of new varieties by plant breeding and the process of re-selection of a variety by taking single ears and multiplying them under proper control. The second method is used to improve the purity and standard of a variety that may have deteriorated under ordinary farm conditions. Once a new variety has been produced, it should be tested under widely varying soil and climatic conditions in order to compare it with existing varieties in respect of yield, quality, and habit of growth. After completion of the trials, it can be decided whether the variety is an improvement on existing varieties and whether it should be recommended to farmers. A stock of seed has then to be multiplied until sufficient quantities are available to be offered for sale as seed.

It will be appreciated that it may be many years, from the time when the first crossing is made, to the stage when the new variety is put on the market. It may be ten years before the breeder is satisfied that he has a 'pure line' possessing the characters desired. The work of testing the new variety will extend over at least three years, and two or three years more are necessary for the seed to multiply in bulk.

* See page 169 for an account of the theory of inheritance worked out by Mendel.

Once the new variety has been introduced into farming practice, there arises the problem of keeping it pure and true to type. In some cases, deterioration may occur through the appearance of unsuspected types of plant, showing that the variety has not been completely fixed as a pure line. Another possible source of contamination leading to deterioration may occur on the farm. If more than one variety of a particular cereal is grown on a farm, there is the possibility of a mixture of seed in the course of threshing unless the machine is thoroughly cleaned out between the threshing of one stack and another. Self-sown plants of another variety are a possible source of contamination to a stock of seed. The growing of cereals for seed needs considerable care and attention to prevent the appearance of impurities that lower the value of the seed.

Modern Improvements in Root Crops

The improvements made in the root crops grown by the farmer are more recent in origin and in some ways more striking than the improvements in cereals. Root crops have been introduced into agriculture only during the past two hundred years, and it is still possible to find growing wild the parent plants from which many of them have been developed.

A wild form of cabbage is still in existence with an erect stem and fleshy leaves bearing some resemblance to a cabbage. From this wild form, the wide range of forms of the cabbage family now grown by farmers and gardeners has been developed. Cabbages of varied sizes and shapes, kales with smooth and curly leaves, brussels sprouts, kohl rabi, and cauliflowers are special types developed from the original wild plant. These forms are the result of mutations which have produced plants with some unusual characteristic which has been retained.

Improvements in plants of the cabbage family have been the result of plant breeding and selection. The plants belonging to the cabbage family are cross-pollinated, which makes the selection more difficult, and greatly complicates the work of the plant breeder as well as the possibilities of keeping a stock of seed true to type. Unfortunately, plants of this family are not only fertilized by plants of their own type, but by any other type. Flowers of a cabbage may be fertilized by pollen from a cauliflower, thus adding considerably to the problem of maintaining purity of stock. As a result of this characteristic, plants intended for seed production are grown in groups as far as possible under conditions of complete isolation, with no opportunity for pollination other than from the group of plants themselves. A stray broccoli allowed to run to seed in a cottage garden may, if near

enough to a crop of brussels sprouts being grown for seed, introduce an impurity. When a new variety of a plant of this type has been produced by a plant breeder, the seed has to be obtained by cross-pollination of several plants all as similar in character as possible, and grown under conditions of isolation.

In the case of root crops such as turnips, swedes, and mangolds, considerable improvement has been made by a continuous process of selection, the critical factor being the amount of dry matter produced from an acre of the crop. A similar method has been used for the improvement of sugar beet, the improvement being measured by the all-important factors of the weight of roots and the percentage of sugar they contain. The wild ancestor of the sugar beet is still found growing in certain coastal areas, but the amount of sugar contained in the wild plant is generally low. The crop was first cultivated in Europe as a source of sugar about 150 years ago, and records available show that from 1838 to 1888 the average sugar percentage increased from less than 9 per cent to about 14 per cent, and from 1888 to the present time there has been a further improvement to a figure over 18 per cent. The standard percentage of sugar for the purposes of determining the factory price of sugar beet in the British Isles is $15\frac{1}{2}$ per cent, and this in itself is an indication of the increase in yielding capacity of the sugar beet. During the same period, there has been an increase in the total weight of roots produced, In the middle of the nineteenth century, the yield was about 8 tons an acre, whereas modern varieties in a suitable season should yield not less than 12 tons an acre.

Sugar beet is a cross-pollinated plant, and the process of selection has to be carried out by taking roots of good size and shape and with a high sugar percentage, and growing them for seed in groups in an isolated position. The seed thus produced is sown a second time and a further selection made so that the roots giving low yields of sugar are eliminated as far as possible. The seed is then multiplied into a commercial strain. Most of the varieties of sugar beet grown in the British Isles are of Continental origin, and for each variety, selection has led to the development of three separate strains, or types. Type E is a high-yielding type, which produces a large root with a rather low sugar content and is best suited for light soils which are not in a very high state of fertility. Type Z is a lower-yielding type with smaller roots, but has a higher percentage of sugar and is the type often grown on rich fen soils where a large-rooted variety would produce oversized roots and an excessive amount of tops. The third type is known as Type N, and is intermediate between types E and Z in respect of both yield and sugar content. In selecting a suitable

variety of sugar beet, it is important to choose the appropriate type for the soil conditions. One effect of the war was the impossibility of obtaining sugar beet seed from the Continent, and work was started on the breeding and selection of varieties of sugar beet more specially adapted to conditions in the British Isles.

Potatoes differ from most other agricultural crops in that they are usually reproduced from tubers, and not from seed produced in their flowers. This is known as vegetative reproduction, and, as no process of fertilization takes place, every new plant should be an exact replica of the one that produced the tuber. All the varieties of potatoes now grown in this country have been developed from tubers originally introduced from South America, and, in the course of being cultivated for a great many years, the size, shape and flavour have been gradually improved. Certain varieties of potato produce flowers that are normally self-fertile, and produce true seeds, and new varieties have been developed by sowing the seed instead of using the tubers. This has given rise to new forms that are kept in being because of vegetative reproduction. Attacks of virus disease lead to rapid deterioration in a potato variety, and this deterioration was responsible in large measure for the introduction of new varieties, in the hope that they would not be affected by this decline in yield. Now that the effect of virus diseases is better understood, it is possible that varieties resistant to these diseases will be produced by plant breeding.

Many new varieties have been introduced by crossing the flowers of one potato variety with another and selecting a seedling possessing certain desirable features, and one of the triumphs of potato breeding has been the production of varieties that are resistant to wart disease. Work has been in progress for a number of years with a view to breeding varieties that are resistant to attacks of potato blight and certain virus diseases. New species of potatoes have been collected from South America and Mexico and brought to this country, where they have been carefully examined and classified. Among these new species may be found some that possess the characteristics desired, which could be used as one parent for crossing with the commercial varieties already in existence. In this way it may be possible to combine the resistance to blight of a wild species with the size, shape, and flavour of tubers of the cultivated potato.

Forage Crops

During the past twenty-five years, work has been started, more particularly at the Welsh Plant Breeding Station at Aberystwyth, on the improvement of the forage crops such as the grasses and

clovers. The work began by a study of these plants, which showed that, as in the case of cereals, there were many different forms of the same botanical species and that they showed considerable variation in habit of growth, proportion of leafy growth, and time of maturity. The farmer uses these crops to provide food for stock, and the chief requisite of a good forage plant is a good yield of leafy herbage. Plants with this characteristic are less likely to produce a good crop of seed, and there has been a growing danger that leafy strains would be lost because the grower of seed tended to produce seed from the non-leafy types. The work of improving the forage grasses has been more difficult than with cereals, because the plants are normally cross-pollinated. Work has proceeded in two directions, those of selecting the more productive strains and of systematic plant breeding. When building up a new strain, plants possessing the desirable characteristics are collected and tested as suitable parents by being crossed by hand between themselves. The resulting crosses produce a wide range of forms. The parent grasses which give rise to undesirable forms are discarded and, in time, a strain is developed with only a limited range of variation. This work has advanced to the stage where a number of strains of grasses have been put on to the market, and they are all designated by a letter "S" followed by a number.

Special strains are available of perennial ryegrass, and each strain possesses some definite characteristic. One strain is late flowering, gives a dense and leafy herbage, and is well suited for use on a grazing pasture, whilst another is more suitable for inclusion in a mixture needed for haymaking because it starts into growth earlier and flowers earlier. It also recovers well after being cut for hay and produces a good aftermath. Similarly, strains of cocksfoot and timothy have been developed for use as grazing plants or to be cut as hay.

Work has also been done on the improvement of red clover and white clover, and the technique of producing new strains is similar to that used for the grasses. One strain of white clover, known as S.100, has become widely accepted and is recommended for inclusion in most permanent pastures or long leys. It is to be expected that newer and better strains will be developed and appear on the market in due course. The making of seeds mixtures suitable for a variety of purposes has been greatly simplified by the introduction of strains of grasses and clovers with definite and standardized characteristics.*

* A detailed description of the Aberystwyth strains of grasses and clovers is not given, but full information on the strains available can be obtained on application to a County Organizer, or to the Welsh Plant Breeding Station, Aberystwyth, Wales.

It has been possible to give only a very brief account of the work that has been done to improve the farmer's crop plants. New advances in knowledge and in the technique of plant breeding will lead in their turn to further improvements. Farmers should obtain all the information possible about new varieties of crops and should take account of any trials being carried out in the district on different varieties. From time to time, leaflets are published by County Organizers or by the National Institute of Agricultural Botany, Cambridge, giving lists of recommended varieties of different crops. In general, the number of varieties available for most crops is bewildering, and it is by obtaining the most recent information on the subject that a farmer can make the best choice for conditions of his farm. The productivity of many farms could be appreciably increased by the use of newer and better varieties ; and when a farmer has discovered a variety well suited to local conditions, he should adhere to it until he is convinced, by a proper system of trial, that it can be replaced by something superior.

PART III
THE PRINCIPLES OF ANIMAL PRODUCTION

CHAPTER I
THE STRUCTURE OF FARM ANIMALS

ALL the livestock of economic importance in farming are known as vertebrates, which is the name given to members of the animal kingdom that have a backbone. The horse, ox, sheep, and pig are also classified as mammals, a class of vertebrates whose chief characteristic is that they suckle their young. They are warm-blooded animals, and have a skin that is covered with hair, and their young are fully developed within the body before birth.

By contrast, birds have a protective covering of feathers and their young are hatched from eggs.

The body of an animal consists in the first place of a skeleton, which is a framework of bones and gives the necessary support to the soft parts of the body. These include the various muscles, the lungs, the organs concerned with the circulation of the blood, the digestive and excretory systems, and the parts that provide for reproduction. The whole body is covered with a skin, which helps to maintain the animal at a constant temperature. The study of the structure of animals is known as Anatomy, and medical and veterinary students have to make a special study of the subject. For the agriculturist, it is only necessary to give a simple outline of the anatomy of farm animals, with special reference to those parts of the body of economic importance from the farmer's point of view.

THE SKELETON

The skeleton of an animal is made up of a number of bones, which are composed largely of mineral matter. The most important mineral constituent is phosphate of calcium, which produces a hard, white substance that is comparatively insensitive to pain and injury and is strong enough to give rigidity to the framework of an animal. A typical bone consists of a hollow tube with two solid ends, and the inside contains a soft and rather fatty substance known as bone marrow. This performs an important function in the manufacture of blood in an animal.

There are a large number of different bones in the skeleton and the separate bones are held together by cartilage, or gristle. In most cases, the place of contact between one bone and another forms a movable joint. The skeleton of a horse contains a total

of 207 separate bones, each with a special function to perform. The skeleton may be divided into the following main parts :—

The skull, which forms the cavity of the head and in which the brain is situated.

The backbone, which is made up of a series of separate bones known as vertebræ, and which stretches from the neck to the tail.

The ribs, which are attached to the backbone and form a large and well-protected cavity, for the heart and lungs.

The hip-bones, which give the general shape of the hindquarters and to which the hind legs are attached.

The shoulder-blades, to which are attached the forelegs.

The limbs or legs themselves, which function as the organs of locomotion.

The relative positions of these main types of bones are shown in Fig. 17.

The head of a farm animal has no special economic importance, though its general appearance may be an indication of an animal's capacity. For example, considerable attention is paid to the difference in appearance between the head of a beef cow and that of a dairy cow.

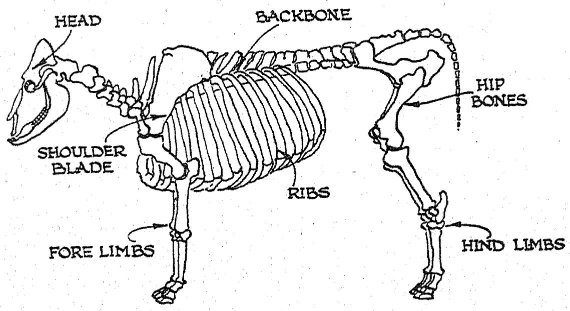


Fig. 17. The Main Parts of a Typical Skeleton

The backbone is a structure of great importance from the point of view of the appearance of an animal, and because of the part it plays as a channel of communication from the brain to the rest of the body. It is composed of a number of hollow vertebræ placed end to end, forming a channel through which passes the spinal cord, which takes the nervous impulses from the brain to the part of the body concerned. The backbone determines the shape of the animal along the " top line." In the case of a horse, the farmer has a preference for an animal with plenty of curves, but with cattle and sheep the back should, as far as possible, form

a straight line. The length of the animal is determined by the length of the backbone ; and in animals that are to be slaughtered for meat, the length of carcass desired by the butcher can be obtained only from an animal with a long backbone.

The ribs play an important part in determining the shape and, in some respects, the performance of an animal. With horses, the ribs should be both flat and long, giving the animal a deep chest and capacious lungs. In the case of cattle, sheep, and pigs, the ribs should be better sprung, to give a round appearance. With these animals, the capacity for good breathing is not of the same importance as the need for ample ribs on which flesh and fat can be developed.

The hip-bones are of special significance on animals kept for their flesh, and great width at this part of the body provides ample space for the growth and development of the more valuable cuts of meat such as the rump and loin. Also horses that are used for draught purposes can develop great strength when the hind-quarters are well grown.

The shoulder-blades are of secondary importance where animals are sold as meat, and the flesh at this part of the body provides the cheaper cuts of meat that are often not very saleable Coarseness at the shoulders is a most undesirable feature in almost all farm animals. In horses, however, the shoulders must be well developed, as they are the point at which the horse applies its strength to pull a load. The shape of the shoulders also affects the general form and action of a horse.

The limbs of most farm animals are of no economic importance and short legs are regarded as a desirable feature, especially in a mature animal. Calves and colts are noted for their appearance of "legginess" when they are born but this disappears as they grow up. In horses, limbs have a special value and this is particularly so in race horses and hunters. With farm horses, the size of the feet and the quality of the hoof are factors of importance in their value.

The different bones of the skeleton are attached to each other at the joints and these are arranged to allow of movement, in some cases to a limited extent and in others quite freely. There are several types of joints found in the body but the two important types are the hinged joint and the ball-and-socket joint. The elbow in man is an example of a hinged joint, whilst the shoulder works on the principle of the ball-and-socket. The smooth movement of one bone against another at a joint is made possible by a covering of cartilage attached to the ends of the bones. The interior of the joint is filled with a clear liquid, which acts as a lubricant to make the movement free and easy.

Flesh and Muscle

The flesh of an animal is supported on the framework provided by the bony skeleton and consists of a large number of different muscles. A muscle is made up of a series of fibres grouped together in bundles. The movement of a limb is caused by the contraction of the limb muscles. When the muscle fibres are stimulated, either by a message from the brain or by some external stimulus such as a mild electric shock, the centre of each fibre swells and in so doing shortens the whole fibre. If the muscle is firmly attached at each end to a bone, its contraction causes the movement of that part of the body. This explains briefly the way in which an animal causes the movement of its limbs. The muscles are attached to the bones by means of tendons, and parts of some bones have a roughened surface to facilitate the union of bone and tendon.

There are two distinct muscular movements that can take place in an animal. One is the voluntary movement of a muscle, which is under the control of the animal through its brain. The muscles connected with voluntary movement have clearly defined fibres, and it is sometimes possible to recognize muscle fibres in a piece of cooked meat. But in addition to these voluntary movements certain of the body processes are carried out by involuntary movements of muscles. An animal does not consciously control the beating of its heart or the digestion of its food, and both call for muscular movement of an involuntary character.

In addition to the muscles, the fleshy parts of the animal's body contain varying amounts of fat. This has no power of expansion and contraction, and if fat is present in too great amounts it may even impede the action of the muscles. Fat is deposited in various parts of the body as a reserve of food that could be used by the animal as a source of energy if at any time the amount of food available was insufficient for its needs. It is a common experience with human beings to find that individuals who do little muscular work and take insufficient exercise are liable to get fat. This condition is wanted in many farm animals when they are being fattened in preparation for sale as meat.

Thorax and Abdomen

The body, or trunk, of an animal is divided into two distinct parts. At the forepart is the thorax, or chest, and at the back is the abdomen, or belly. These are separated from each other by a partition of muscle called the diaphragm, and there is no opening or connection between the two cavities. The thorax is well protected by the ribs, because it is here that the heart and lungs are found and these are probably the most vital parts of the

animal. The heart is responsible for the circulation of the blood within the body and it is a certain sign of the cessation of life when the heart stops beating. On either side of the heart are the lungs, which are concerned with the breathing of the animal, and they too are essential to its existence.

In the abdomen are found the stomach and the intestines, which together are responsible for the digestion and absorption of the food eaten by the animal and for the elimination of the solid indigestible matter. Other organs found in the abdomen and associated with digestion are the liver and pancreas, or sweetbread, and in the same region are the kidneys, which dispose of the liquid waste products. The reproductive organs are situated in the abdominal region, though further to the rear of the animal. Here is found the womb of the female animal, in which the young develop before birth, and one of the obvious signs of pregnancy is the increased size of the abdomen. The function of the organs in the thorax and abdomen will be discussed in greater detail in a later chapter.

The Skin

This is the external covering of the animal and its most important function is in maintaining the body temperature of the animal at a more or less constant level. When the temperature of the body rises unduly, an extra supply of blood goes to the blood vessels near the surface of the skin and the surplus heat can be lost by the cooling effect of air on the skin. If this does not cause a drop in the temperature, the skin secretes sweat through special glands : when this evaporates there is a further loss of heat. Some animals are better supplied with sweat glands than others. Horses have a great number of them and by sweating profusely maintain a constant body temperature very easily. Cattle, sheep, and pigs have comparatively few sweat glands, and a rise in temperature quickly leads to distress. A dog has none of these glands and tries to cool itself by exposing its tongue to the air. In the process of sweating, animals dispose of certain waste products from the body.

One of the surest indications that an animal is suffering from some disease is a rise in its normal temperature, since in conditions of health the body maintains a fairly constant temperature. The normal temperatures of farm animals are higher than that of humans, which is 98·4° Fahrenheit, and should be 100° to 101° F. for horses, 101° to 102° F. for cows, 103° to 104° F. for sheep, and 102° to 103° F. for pigs.

The skins of farm animals are of some economic importance. The hides of cattle are tanned and used for leather, and pigskin can be made into a soft kind of leather. Hairy animals develop

a thicker coat during the winter months as a protection against the colder weather, and as the weather gets warmer in the spring the old winter coat is thrown off. The animal is sometimes clipped to get rid of its winter coat and this is most frequently done for horses. Sheep have their winter coat taken off at the time of shearing in early summer. In some countries the wool from the sheep is of almost equal importance to the meat they produce.

The Teeth

The obvious use of teeth is the part they play in the chewing, grinding, and mastication of food in the mouth prior to its digestion in the stomach. There are three main kinds of teeth : the incisors, or front teeth, which are sharp-edged and used mainly for the cutting of food, especially in the grass-eating animals ; the canines, or eye teeth, which are specially well-developed in flesh-eating animals and are used for tearing off the food and cutting the food in the mouth ; the molars, or grinding teeth, with flat, rough surfaces between the upper and lower groups of which the food can be finely ground. The horse and the pig have a number of all these different teeth in both upper and lower jaw ; but the ox and the sheep have no incisor, or canine, teeth in the upper jaw, their place being taken by a hard pad against which the incisors in the lower jaw bite the food.

Animals are usually born without teeth and develop a temporary set while they are quite young. In time, these give way to permanent teeth. As the change from temporary to permanent teeth takes place at regular ages, it is possible to judge the age of an animal by examining its teeth. A horse develops a full mouth of permanent teeth at the age of five years. After all the permanent teeth have appeared, the age of a horse can be told by examining the extent to which the front teeth have been worn down, leaving a characteristic pattern at different ages.

Birds

The most distinctive feature of birds is the covering of feathers, which grows on the skin in place of the hair found on mammals. In the skeleton of a bird, the breastbone is broad, and attached to it are the powerful muscles that are needed to enable the bird to fly. The body cavity in birds is not divided by a diaphragm as in mammals. The digestive system is very different in character from that of mammals and will be discussed in a later chapter. For purposes of reproduction, birds lay eggs with hard shells containing an embryo, which, when kept at a warm temperature for a definite period of incubation, develops into a chick. The yolk of an egg is the food provided for the nourishment of the chick during the period of incubation.

Chapter 2

THE FUNCTIONS OF THE ANIMAL BODY

PLANTS and animals are living organisms and certain processes have to be carried out if they are to remain alive. In plants, the essential nutrients are comparatively simple in character and consist of carbon dioxide from the air and mineral salts and water from the soil. Animals depend on plants for their food, and the food materials taken in by animals are more complex and must be broken down into simpler substances before they can be utilized.

All animals are ultimately dependent on plants for their nourishment, the herbivorous, or grass-eating, animals being directly dependent whilst the carnivorous, or flesh-eating, animals rely indirectly on the food supplied by plants. Generally in the world of nature, plants are capable of existing without the aid of animals but the converse is certainly not true.

Animals require a source of energy to enable them to live, and this is derived from the breaking down of the complex constituents of the plants they eat. They also need a supply of oxygen to make this energy available, and this is obtained by the process of breathing. The different processes that take place in the maintenance of life are known as metabolism and consist of three main functions. The food is first taken in by the animal, and broken down by digestion. The useful products of digestion are then transported throughout the body by the circulation of the blood. Finally, the body must dispose of the material that cannot be digested and of the waste products arising from the different processes.

The Digestive System

The organs concerned with digestion are required to break down the food into a form in which it can be absorbed by the blood and transported to the parts of the body where it is required. Food contains three main substances of importance in nutrition: carbohydrates, fats, and proteins. In addition to these, the food consumed must contain adequate amounts of mineral salts and vitamins. The composition of the feeding-stuffs of the farm is dealt with in a later chapter.

The digestive system as a whole is known as the alimentary canal. In the simpler living organisms such as insects the alimentary canal is little more than a tube, which starts at the mouth and continues through the length of the body to the anus, where undigested material is passed out of the body. In farm animals, the alimentary canal is more complicated in structure and con-

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sists of the mouth, the pharynx situated in the throat, the gullet or œsophagus, the stomach, the small intestine, and the large intestine.

The food is taken in at the mouth, where it is crushed by the teeth and mixed with saliva and brought into a moist condition so that it can be easily swallowed. In the act of swallowing, the food has to pass the pharynx, which is situated at the back of the throat and is constructed in such a way as to guide the food into the gullet and to prevent it getting into the windpipe, where it would cause choking. The food travels down the gullet, which is a long tube leading from the throat to the stomach, passing through the diaphragm. The stomach is an extension of

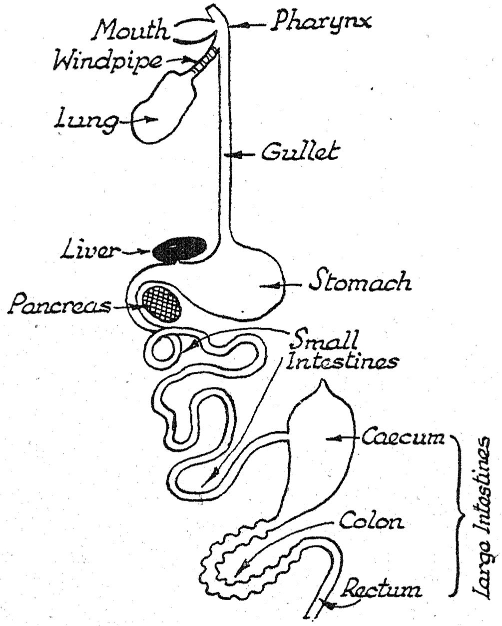


FIG. 18. DIAGRAM OF THE DIGESTIVE SYSTEM

the gullet in the form of a bag, in which the food collects. Here it is mixed with digestive juices and is churned round and round, and the process of digestion begins in the stomach. From the stomach is an opening into the small intestines, which are of considerable length and lie coiled up in the abdomen. The final digestion of the food takes place in the small intestines and here the soluble foodstuffs are absorbed into the blood through the walls of the intestine. The undigested residue passes into the large intestines, which consist of three separate parts : the caecum,

the colon, and the rectum. In most farm animals, the caecum is used as a store for water, and there is a further breaking down of a part of the food material in the colon by the action of bacteria. This is of special importance in the case of ruminants. Finally, the undigested residue passes into the rectum and is voided by the animal as dung.

Cattle and sheep are known as ruminants, because they have the habit of chewing the cud. In these animals, the stomach is modified into four separate parts, which are called the rumen, or paunch, the reticulum, the manyplies, and the true stomach. The paunch has the largest capacity of the four parts and in the cow holds from 50 to 60 gallons of food material. When the food is first taken into the body it is not chewed very thoroughly but passes into the paunch. Later, when the animal is at rest, the food is brought back into the mouth in small amounts and given a more thorough chewing and mastication. When it is swallowed a second time it is in a more liquid condition and does not go into the paunch but passes through the second and third compartments into the stomach proper. Here the first stage of digestion proper begins, and from then on the process is similar to the general system already described. The capacity of the ruminants to store food in the paunch was developed as a means of defence when they were living as wild animals. A large quantity of food was quickly eaten and stored and the animal then sought a place where the food could be properly masticated and digested at leisure and in safety.

The actual digestion of the food is done by a series of ferments, or enzymes, which are mixed with the food at different stages in its passage through the alimentary canal. These ferments act on the various constituents of the food and break them down into a soluble form. They are secreted from glands, beginning with the salivary glands in the mouth. The saliva is secreted when food goes into the mouth and contains an enzyme known as ptyalin, which acts on starch and turns it into soluble sugar. There are glands in the wall of the stomach that secrete gastric juice containing a ferment called pepsin, which breaks down the proteins in the food. Gastric juice contains some hydrochloric acid, to keep the contents of the stomach in a slightly acid condition so as to kill any bacteria that may have been taken in with the food. It is also capable of curdling the liquid milk it receives, by the action of an enzyme called rennin.

When the food enters the small intestine, it is first mixed with a substance called bile to neutralize the acid from the stomach, and this enables the fatty substances to get thoroughly mixed and in a state in which they can be acted upon by enzymes. Finally,

the food is acted upon by the pancreatic juice secreted by the pancreas, which contains three separate ferments. One, called amylopsin, acts on the carbohydrates ; a second, called trypsin, breaks down the proteins ; and lastly, there is steapsin, which completes the digestion of the fats.

Circulation of the Blood

The action of digestion is to bring the food into a soluble condition for transportation to all parts of the body. The distribution of the soluble food material is done mainly by the blood, which is also responsible for collecting some of the waste products for elimination. There is another circulatory system in the body, of a clear liquid known as lymph, which is partly independent and partly connected with the blood system.

Blood is at first sight a thick red liquid, but when seen under the microscope it is found to consist of two distinct parts. The liquid

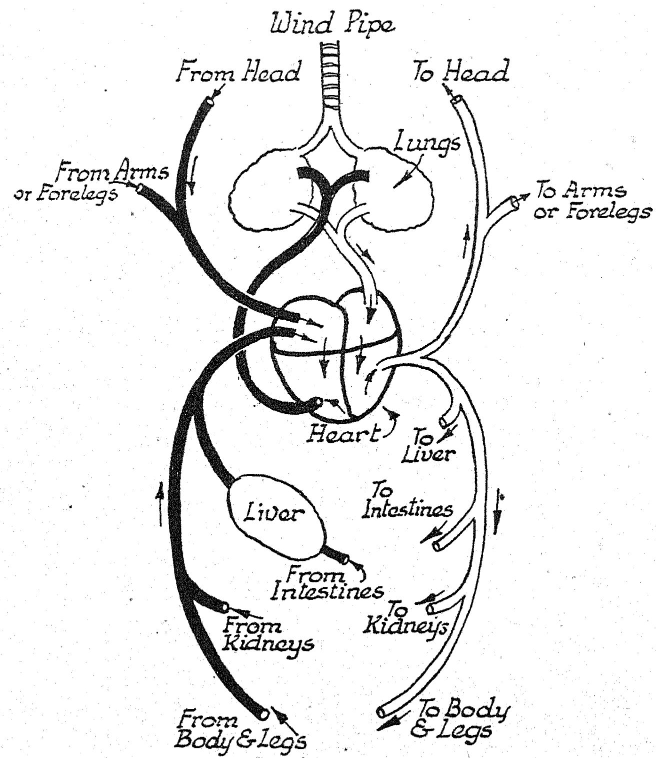


Fig. 19. Diagram of the Circulation of the Blood. (seen from the front)

part is colourless, but suspended in this liquid are a large number of small round and flat bodies, which are bright red in colour, and a smaller number of white bodies with no very definite shape. These bodies are known as red and white corpuscles respectively. The red corpuscles carry the oxygen which the blood takes to the different parts of the body and bring back the carbon dioxide which is formed in all parts of the body when any muscular activity takes place. When fully charged with oxygen, the corpuscles are a brighter red in colour than when charged with carbon dioxide, and this accounts for the slight variations in colour of the blood at different stages of its circulation.

The blood is in continual circulation throughout the body: starting from the lungs and heart, it passes into the arteries and thence to small capillaries, where it is transferred to other capillaries and by the veins goes back to the heart and lungs. The heart is essentially a central force pump, provided with powerful muscles to maintain the blood in constant circulation. The heart is divided into four separate compartments, the two upper ones being known as auricles and the two lower as ventricles. The blood is received by the heart in the auricles, passes through valves into the ventricles, and is pumped out from them. The arteries in which the blood goes from the heart start from the ventricles, and the veins, which bring the blood back to the heart, empty themselves into the auricles.

The blood for circulation comes from the lungs, where it has been charged with a fresh supply of oxygen. It enters the heart by the left auricle and then through a flap valve into the left ventricle. The beating of the heart, which is caused by the contraction of the heart muscles, forces the blood from the left ventricle into the main artery. After leaving the heart, the main artery branches off to the different parts of the body, separate branches going to the head, the arms, the abdomen, and the legs. The artery to the abdomen again splits into two branches, one for the liver and one for the kidneys. The branches further divide until they become small fine capillary tubes, which are so fine that they can release the oxygen and the food substances that the blood is carrying. In exchange, other capillaries collect the waste products, especially carbon dioxide, and lead gradually to veins, which eventually join the main veins and in turn merge into one vein, which takes the blood into the right auricle. The blood, having completed its circulation of the body, is impure, and passes into the right ventricle, and thence by a special artery to the lungs, where it gets rid of the carbon dioxide it contains and is recharged with oxygen. It then returns to the heart to begin its journey through the body once again.

As has been stated, the blood carries with it food materials and oxygen. The oxygen is needed to enable the energy contained in the food to be used by the muscles concerned. The food materials include soluble sugars and proteins, which are absorbed through the walls of the small intestine, and the blood passes by way of the liver to the heart.

Small particles of fat cannot be absorbed in the same way as the sugars and proteins, and they are taken into the blood by the lymph. Lymph is a colourless liquid, which is apparent when a blister is caused on the skin. It circulates in a different set of channels, known as lymphatic ducts or vessels, which are connected with the blood vessels at certain points. At some places, the lymph vessels enlarge into glands, which function as a source of new white corpuscles for the blood. The lymph system is also capable of preventing the entry of bacteria into the blood stream and plays an important part in the maintenance of the health of the animal.

Respiration

One of the obvious signs of life in an animal is that it continues to breathe. Respiration is the term applied to the function of breathing and it consists of the taking in of air to the lungs by way of the nose and mouth and the subsequent release of that air. When the air is taken into the lungs, it contains a supply of oxygen, but the air that is breathed out contains less oxygen and a greater amount of carbon dioxide and water vapour. The presence of water vapour is very apparent when one is breathing out on a cold morning. In a room where there are a large number of people the oxygen content of the air goes down and the room is then described as stuffy, owing to the accumulation of carbon dioxide.

The need for a supply of oxygen to the blood has already been pointed out, and the oxygen required is obtained from the air, which is breathed in through the nose and passes into the lungs through the windpipe, which divides into two branches to serve the two lungs. The lungs are composed of a mass of spongy tissue made up of air tubes, which get smaller and smaller as they branch and divide. The very small air tubes are surrounded by very small blood vessels, and here the blood exchanges its waste products (carbon dioxide and water) for a fresh supply of oxygen. The waste products are then expelled from the lungs in the act of breathing out. When the blood goes to the lungs it is full of waste products and is slightly purple in colour, but after the exchange, which involves the absorption of oxygen, it regains its bright red colour. It then returns to the heart for circulation round the body once again.

It can be seen that respiration is essential to life, and death is rapidly caused if an animal is unable to breathe in oxygen. This shows the great importance of fresh air to all farm animals. This is in ample supply when the animals are out of doors, but when they are kept in houses a good system of ventilation is needed if they are to obtain a good supply of oxygen.

Disposal of Waste Products

Excretion is the term applied to the disposal of waste products formed by metabolism, and the organs concerned with it are referred to as the excretory organs. The waste products of muscular action, consisting of carbon dioxide and water, are passed out of the body by way of the lungs.

The greatest part of the food waste to be removed from the body is the solid indigestible residue that is left after digestion is completed. As the food passes through the alimentary canal, the food materials abstracted from it are gradually absorbed into the blood. By the time the food reaches the rectum, the animal has got all that is useful from it and the residue is removed from the body as fæces, or dung. The condition of the dung of an animal is some indication of the food it is eating. In the summer, when grass forms the main bulk of the food, the fæces are almost liquid in consistency, whereas in winter, when hay, straw, and meals form the main part of the diet, the dung is much firmer. With some diseases, the fæces are liquid and the animal is then said to be scouring.

The skin plays a small part in the excretion of waste products by means of the sweat glands it contains, and the principal product disposed of in this way is water. Other organs of excretion are the kidneys, which are responsible for the elimination from the body of the waste products formed by the breakdown of proteins. When the muscles of the body are performing some activity, there are a number of breakdown products that are poisonous in character. If these were allowed to accumulate, the animal would gradually be poisoned. They are collected by the blood and taken to the liver, where they undergo a chemical change, which renders them harmless to the animal. From the liver they pass to the kidneys, which act as a kind of filter and abstract the waste products from the blood. The waste products are then taken to the bladder and are excreted in solution in the urine.

The process of metabolism in the animal can now be summarized. It consists of the taking in of food, from which the blood stream absorbs the digestible matter. This is transported through the body by the blood, together with a supply of oxygen, which

is obtained from the lungs. The blood system is responsible for collecting the waste products, some of which are expelled from the lungs and others excreted by the kidneys. If the amount of food eaten by the animal contains more nutrients than are needed for the maintenance of life, the surplus is available for such purposes as the production of milk or an increase in weight or the performance of work. If the gains of the blood in food materials are evenly balanced with the loss of waste products, the animal remains alive without losing weight, but there is no surplus for productive purposes. If for some reason the animal is deprived of its food, it lives for a time on its own reserves, particularly the fat stored in the body. The animal remains alive but gradually loses weight. The same thing happens if the food is insufficient in quantity for the needs of the animal. If the farmer wishes to avoid a loss of condition in his animals, he must feed them in accordance with their requirements.

Metabolism in Birds

In principle, metabolism in birds is the same as in mammals. There are, however, differences in the structure of the organs concerned. The mouth differs from that of mammals by the absence of teeth, which are replaced by a horny beak. The alimentary canal, after leaving the back of the mouth by the gullet, widens into a thin-walled crop, in which food is stored. From the crop, the canal passes to a small stomach where the gastric juices are secreted. This is followed by the gizzard, which is composed of thick walls of muscle and a horny lining, and is constructed in two parts so that the food can be ground between two rough surfaces. The grinding is helped by the small stones and pieces of grit which are swallowed with the food. After passing through the gizzard, the food is in a finely ground condition, and the final processes of digestion are much the same as those that have been described for the mammal. There is, however, no bladder in birds and the waste nitrogenous products from the kidneys pass into the same channel from which the fæces are eliminated.

Chapter 3

REPRODUCTION IN FARM ANIMALS

IT is a characteristic of living organisms that they must reproduce themselves and so enable the existence of their kind to continue. So far as the common farm animals are concerned, there is little difference in the metabolism of male and female animals, and the most obvious distinction between them is in the respective sizes of the two sexes. The real distinguishing feature between male and female is in the organs of reproduction, and the male and female have separate functions in the process of reproduction.

Organs of Reproduction

The essential organs of reproduction in the male are the testes, which are a pair of glands situated outside the body cavity and contained in a sac known as the scrotum. The glands are responsible for the formation of the male sex cells, called spermatozoa. These are minute in size and can be seen only under a microscope. A sperm consists of an egg-shaped head attached to a tail, which is about three times the length of the head and is used by the sperm for swimming about in the fluid in which it is secreted. The cells are produced in the testes and are stored near these glands, and at the time of mating several million of them are passed into the female. They are contained in a fluid in which the sperm can move, and this liquid secretion is known as semen.

In the female, the essential organs of reproduction are contained within the body and consist of two organs called ovaries. At regular intervals, which vary in different animals, the ovaries shed one or more "eggs." These are small and barely visible to the naked eye, but in all respects are similar to a hen's egg in miniature without the hard shell. In size, they would be rather smaller than the head of a pin. When the egg has been shed from the ovary, it drops into the mouth of a tube situated immediately below the ovary. The tubes from the two ovaries later join to form one channel, which passes to the exterior. A part of this channel becomes the womb when the animal is pregnant ; from the womb to the exterior, the channel is known as the vagina. The semen from the male is deposited in the vagina at the time of mating.

When the sperm enter the vagina, they propel themselves along the channel until they come to the uterus, which in due course becomes the womb. If the mating has been made to coincide with the shedding of an egg from the ovary, the sperm come into

contact with the egg, and one of them attaches itself to the egg. When this fusion takes place the egg is said to be fertilized. Fertilization usually takes place soon after the egg leaves the ovary, and the fertilized egg passes down into the uterus and becomes attached to the lining. Here the development of the two original cells continues and the nourishment required is provided from the blood stream of the mother. The newly developing offspring is known as a fœtus and it remains in the womb until the time of birth, when it is expelled through the vagina and starts an independent existence.

The sexual reproductive organs have an important effect on the body of the animal. They secrete into the blood stream certain chemical substances, which affect the size, shape, and appearance. Thus, a bull develops well-defined masculine characteristics, such as a massive body and a large powerful head and neck. When the testes are removed, as in castration, the resulting steer is very different in appearance. He is incapable of mating with a female and is generally quieter and more easily controlled. The ovaries are sometimes removed from female pigs, an operation known as spaying, and they fatten more readily when treated in this way.

Male animals are capable of performing the act of mating, or 'serving' a female, at any time of the year. The female, on the other hand, accepts service only at certain definite times, and is then described as being "on heat" or "in season." The times of mating vary with different animals. A bitch comes on heat once every six months. With sheep, there is a well-defined mating season during the autumn when the periods of heat occur every 14–18 days. Mares and cows, particularly the latter, come on heat at intervals of three weeks throughout the year, though the periods of heat may cease in the mare during the winter. Sows can be mated regularly all the year round with an interval of three weeks between the periods of heat.

These periods of heat, when the female can be mated, are associated with the function of the ovaries, from which a new egg or, in some farm animals, a number of eggs are shed at this time. The eggs pass into the tubes just below them, where, if a service has taken place, they come into contact with living sperm and fertilization takes place. If for any reason fertilization is not effected, the ovaries develop another egg, which is shed at a later period of heat. It is sometimes difficult to observe whether an animal is on heat and the usual sign is some external discharge from the vagina. Cattle often show signs of being on heat by mounting the backs of other animals in the field. With young heifers that have not had a calf, it is a common practice to allow

a bull to run with them to make certain they are served at the proper time, though this has the disadvantage that the date of calving is not known with certainty. It is more difficult to detect the period of heat during winter, and some cowmen make a practice of leading a bull along the cowshed once a day to ensure that no opportunity of service is lost. When sheep are mated, the ram, or tup, runs with the ewes and the under part of the ram is often coloured. When a ewe has been served, the colour rubs off on the ewe's back and this indicates whether a service has been made.

The time during which the fœtus is retained in the womb is known as the period of gestation. During this time, the two cells that originally fused multiply and gradually form the different parts of the new animal. The developing embryo, as it is sometimes called, is nourished by the mother, and a mother requires special feeding during pregnancy to maintain herself and her embryo. The normal periods of gestation in the farm animals are :—

Mare—11 months.	Sheep—5 months.
Cow—9 months.	Pig—4 months.

Normally, mares and cows produce one young animal from each pregnancy, though twins and even triplets are quite common. If twin calves consist of one male and one female, the female twin is known as a 'free-martin' and is not capable of breeding. With sheep, the lambs may be produced singly, as twins, or as triplets, but the flockmaster prefers ewes that regularly produce twins. Pigs have comparatively large litters, and from 12 to 15 piglets may be born in a litter. A good breeding sow should rear 8-10 pigs from every litter she produces.

Before a female can be used for breeding purposes, it is important that she should be well grown, so she should not be mated at too early an age. On the other hand, it is uneconomic to delay service longer than is necessary. Young horses are usually mated at three years of age, and the usual age of breeding in cattle is 18 to 24 months, in sheep is 18 months, and in pigs 12 months. Males can be used for service at a very young age, though they should not be used to excess. The minimum ages are 12 months for horses, 12 months for bulls, 6 months for rams, and 6 months for boars.

Artificial Insemination

Although only one sperm is needed to fertilize an egg, the male produces several hundred millions of sperm at each mating. A modern technique has been developed in an effort to make more economic use of the large numbers of sperm produced, most of

which are not utilized. The semen from the male is collected in a specially constructed rubber vessel, and after collection is diluted with certain feeding substances such as egg yolk. In the case of cattle, the sperm survive for two or three days after they have been produced. When the cow comes on heat, a small quantity of the semen is injected into the vagina by a glass syringe, and fertilization usually takes place. In this way, the semen collected from a bull can be used to serve up to fifteen cows instead of the one by the normal method of mating, Thus, the semen from a valuable pedigree bull can be used to fertilize a large number of females.

The new technique is being developed at a number of centres where bulls of two or three breeds are kept, and the semen is transported from the centre over a wide area for the service of cows on heat. With this method, a small farmer can have all the advantages of service for his cows from a valuable pedigree bull at a low cost and without the necessity of keeping a bull on his farm. The development of artificial insemination will enable the type of stock in a district to be improved rapidly with the use of only a small number of high class bulls. It is not unlikely that, in the course of time, every farmer will be within easy reach of a centre from which his animals can be inseminated.

Reproduction in Birds

Reproduction in birds is very different in character from that in mammals. The female cells are produced by the hen and are fertilized by the cock by the act of 'treading.' When the two cells fuse, they are surrounded by a supply of food and covered with a shell, to form the egg that is laid by the hen. The embryo chick in the egg can only be developed by keeping the egg at a temperature of 102–103 degrees Fahrenheit for three weeks. Naturally, this is done by the hen sitting on the egg ; but the chick also develops in the artificial heat of an incubator.

Chapter 4

PRODUCTION OF MILK AND MEAT

THE distinguishing feature of mammals is that the females secrete a supply of milk in their mammary glands to suckle their young from the time they are born until they are able to consume more solid forms of food. The capacity of the mother to feed the young during the early part of their lives has an important effect on the subsequent growth and development of animals. Thus the development of the mammary glands, which are known as the udder, is of importance in all farm animals, and especially in the case of dairy cows. The milk they produce is not only used for the feeding of the calf but is also used for human consumption.

Milk Production

The mammary glands in a virgin heifer are comparatively small but there are external indications of an udder in the form of a small baggy structure and four small rudimentary teats. After mating, little change takes place in the udder for about five months; but from then to the end of pregnancy, the glands are stimulated into growth by certain secretions from the sexual organs. The milk, which is produced when the calf is born, comes from specially developed cells in the udder and these cells begin growth after five months of pregnancy. The amount of milk the animal will produce after the calf is born depends on the growth of these cells, and at this stage the pregnant heifer should be properly fed to encourage the maximum development of the milk cells. The food should be rich in proteins, the body-building substances, rather than in fat, and the practice of 'steaming up' a cow or heifer before calving is done to encourage the proper growth of the milk-producing cells. When a cow that is already in milk has been mated again and is in the fifth month of pregnancy, the milk yield drops. At about eight weeks before calving she must be allowed to 'dry off' and must not continue to produce milk right up to the time of the next calving. The cow cannot secrete milk and develop milk-producing cells for the next lactation at one and the same time.

When a cow has calved, the first secretion of milk is known as colostrum and is thicker in consistency than normal milk. It is rich in protein and has properties to prevent constipation in the newly born calf; it should always be fed to the calf either by suckling from the mother or by being drawn off and fed from a

bucket. The first secretion of milk is not suitable for human consumption.

The period that a cow remains in milk is called a lactation and the yield of milk in a lactation is used as the basis of comparison between one cow and another. The daily amount of milk that a cow produces increases for about six weeks after calving, remains constant for a period of from ten to twelve weeks, and then gradually falls off. If the cow is mated and becomes pregnant again, the yield will probably fall rapidly after the fifth month of pregnancy. The length of a lactation should be from 38 to 44 weeks, and is dependent partly on the time of the year at which the calf is born. Cows that calve in the spring will by the autumn have reached the stage where they are giving a steadily decreasing yield, and from October onwards the yield drops more rapidly, until the cow finally goes dry in December or January. The yield of a cow that calves in the autumn starts to fall by the end of the winter; but with the arrival of fresh young grass in the spring, the yield recovers for a time, then it decreases again and the cow finishes milking about August. This increase in the spring has the effect of prolonging the period of the lactation and increases the total yield for the lactation.

The two factors of greatest economic importance in the production of milk are the total yield in the lactation and the percentage of butter fat contained in the milk. By law, this must not be less than 3 per cent if the milk is to be sold as whole milk for human consumption. A number of factors affect the yield of milk in a lactation. Firstly, there is the breed of the animal: dairy breeds have been selected for their yield of milk for many generations, but there are still large variations between the dairy breeds in their capacity for producing milk. From records kept at the London Dairy Show, the variation in the daily yield of milk of cows from a number of different breeds, all of the same age and at the same stage of the lactation, has been from 3½ to 5½ gallons a day. As already discussed, the month of calving affects the yield of milk for the lactation, whilst a subsequent mating causes a reduction in the milk yield. The yield varies according to the age of the cow and the number of lactations she has given. The yield rises up to the time of the sixth calf and falls as the animal gets older. In some cases, the yield in a lactation is affected by the length of time that the cow was dry before calving. Lastly, the yield depends on the proper feeding of the animal, and the ration must be adequate to provide both for the maintenance of the animal and for the production of milk.

The butter fat content of milk is almost entirely an inherent character of a cow, and some breeds, notably the Jersey and

Guernsey, produce milk with a very high percentage of fat. The fat content of milk from cows of these breeds is in large globules : it is very suitable for butter making and rises readily to the top of a bottle of milk. The amount of butter fat is not affected to any appreciable extent by the feeding of the animal, though its quality may be affected by the use of foods containing an oily type of fat. The greatest amount of fat is contained in the last milk to be drawn from the udder, and this shows the importance of stripping the cow thoroughly at the end of each milking. This has to be done by hand where a milking machine is used. In butter making the colour of the fat is a matter of some economic importance, as butter of a pale colour is not popular. The colour of the butter fat is mainly influenced by a substance known as carotene, which is found in green foods, and for this reason butter is always a better colour in the summer, when grass forms the major part of the ration. The colour can be maintained to some extent during winter by feeding a green crop like kale, or silage that has been preserved so as to retain its green colour and hence its carotene content.

Meat Production

With beef cattle, sheep and pigs, the production of meat is the factor of supreme economic importance. This is a matter of the growth and development of the animal. Growth is a continuous process from the time when the egg is first fertilized until the animal reaches maturity. At the same time, another process is going on, which may be described as development and which includes the changes taking place in the shape of the animal. The actual growth of the animal can be measured by the increase in weight that takes place in a number of weeks, but this alone does not give a clue to the changes in shape that are taking place. It is a matter of common observation that animals when they are born have heads and legs out of proportion to their bodies by comparison with mature animals. From an economic point of view, the head and legs of an animal are of no importance, and it is the other parts of the body, especially the loins, that are valuable as meat. The animal as it grows changes the relative proportions of its body, and the animal that attains this change of shape and is ready for sale to the butcher at an early age is described as being early maturing. This is equally true of cattle for beef, sheep for lamb and mutton, pigs for pork and bacon.

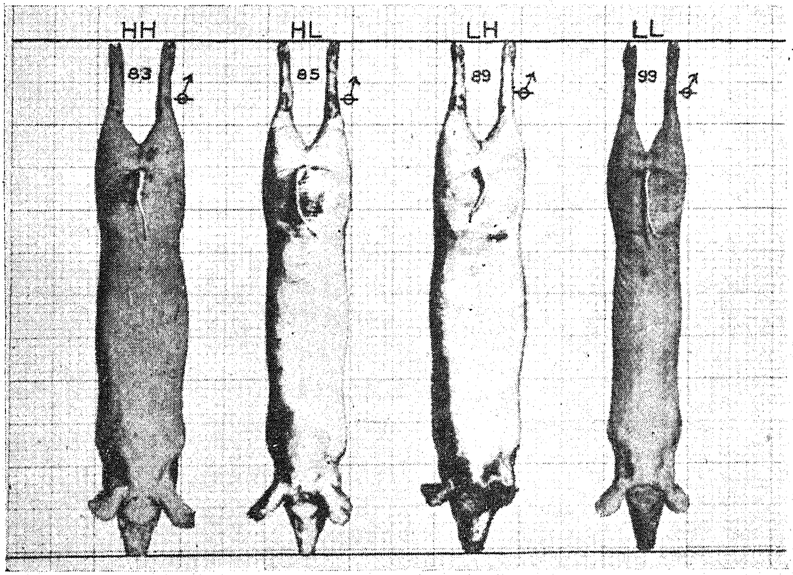
The two main factors that affect the shape of the animal as opposed to its total weight are the breed of the animal and the method of feeding. All domestic breeds of farm animals have been developed from wild types. The shape of a newly born animal exhibits much the same characteristics as that of fully

grown animals of wild unimproved types, which are leggy and have large heads. Improvements were first started by selecting animals with a better shape, and the process of selection has gone on ever since. Breeders naturally discard the badly shaped animals and breed from those of a better shape. With cattle, the process of selection has gone to the point where the breeds have developed into dairy, dual-purpose, and beef breeds. Among the beef breeds, there are some that mature earlier than others, two noteworthy breeds with this characteristic being the Hereford and the Aberdeen-Angus. Bulls from this breed are often used to cross with other beef breeds to produce calves that mature at an early age.

In sheep, the early maturing breeds are the Down breeds and they are often used for crossing with ewes of the heavier and slower-growing grassland sheep. This is an excellent cross for early lamb production, as the ram comes from a short-legged and early maturing breed and the grassland ewes make excellent mothers for suckling the young lambs. With pigs, the differences between breeds has developed to the point of their separation into breeds for pork and breeds for bacon. Thus a pork breed such as the Middle White goes through its growth changes more quickly than a bacon breed like the Large White. A Middle White at about four months old weighs about 100 lb. alive and can be sold as a porker, its hams being well developed to give a saleable leg of pork. A Large White at the same age and weight is undeveloped and has a high proportion of bone to flesh in its body. The full development of a good shape in a Large White comes at a bacon weight of 200 lb. alive. At that age, the Middle White is too deep in the body and too fat to give a good side of bacon. An early maturing breed like the Middle White has, when it weighs 100 lb., a body shape and proportions similar to those of a late maturing type like the Large White at a weight of 200 lb.

The feeding of farm animals affects both the growth and the development of the body. These processes begin when the animal is born, and for the first period of their lives young animals are dependent on the milk supply of their mothers. Animals that are given a good start in life increase rapidly in weight and are always at an advantage compared with animals that do not receive a sufficient supply of milk. During the early part of its life an animal has to develop the skeleton and the vital organs such as the lungs, heart, and digestive systems. If an animal is fed on a limited ration, these parts take precedence at the expense of the early development of muscle and later of fat. A generous ration is essential if early maturity is desired. An animal from a breed possessing the faculty for early development will not develop early if fed on an inadequate ration.

A number of experiments have been carried out to demonstrate the extent to which the shape of fattening pigs and sheep is affected by the level of feeding. At the beginning of an experiment with pigs, the animals were divided into two groups one of which was fed a generous ration and the other kept on a more restricted ration. At the age of sixteen weeks, one half of the group that started on a good ration were continued at this level until they reached a liveweight of 200 lb., which they did in 168 days, when they were killed and their carcasses photographed. The other half of this group were changed over at the age of sixteen weeks to a more restricted diet, and they took 196 days to reach 200 lb. liveweight. At the same age, the group of animals that started



(Photo by McMeekan and Hammond)

FIG. 20. BACON CARCASSES: EFFECT OF FEEDING

on the low ration were divided into two lots, one of which was put on to a generous ration and took 196 days to reach a weight of 200 lb. The others were kept on a low ration and it was not until 315 days that they had reached the same liveweight.

The different shapes of the animals at 200 lb. liveweight can be clearly seen in the photograph (Fig. 20). The best carcass from the point of view of the bacon factory appears to be that from the animal that was started well and then kept on a restricted ration though there is not much difference between that and the carcass from the pig that was well fed throughout its life. This high

standard of feeding brought the animal to 200 lb. liveweight in 168 days, which meant a substantial saving of labour compared with the animal that went on to the restricted diet and took 196 days to reach bacon weight. There is nothing to be said in favour of the carcasses of the pigs that were given a bad start in life, even when they were fed more generously at a later stage.

The natural distribution of breeds of farm animals and the different types of animals kept in various parts of the country are influenced to some extent by the natural supplies of food available and this in turn affects the rate of maturity. In districts with a plentiful supply of natural food, it is more economic to keep one large animal than two small ones, since the proportion of food required for maintenance alone is not so high. Where natural herbage is scanty and not capable of giving enough surplus nutrition above the maintenance requirements of larger animals, sheep and goats replace cattle as the natural type of farm animals. The Southdown breed of sheep is small and early maturing and has developed on the chalky downs, where the grazing is not very productive, whereas the grassland sheep associated with grazing of higher quality is a larger animal.

The final process of maturing in farm animals and one of special importance in beef production is the deposition of fat in the body. This is done in a regular sequence and the first deposition of fat is around the kidneys. In dairy animals, there is little fat in the body except on the kidneys. The next stage in a fattening animal is the layer of fat that is laid over the muscles and gives the animal a well-rounded and plump appearance. The final stage of fattening consists of a quantity of fat being intimately mixed with the muscle fibres. Meat so interspersed with fat is referred to as "marbled" and is more tender than lean meat. It is the early development of marbling that characterizes the early maturing beef animal, and old bullocks must be well finished before they are killed if the meat is to be tender and of good flavour.

The weight of meat obtained from an animal is known as the carcass weight and is usually expressed as a percentage of the liveweight of the animal. The more fat that has been stored by an animal in its body, the higher is the killing percentage. In beef animals the percentage may vary from 47 per cent to 60 per cent and the carcass weight is a good indication of the quality of the meat.

CHAPTER 5

ANIMAL BREEDING

IT is a matter of great economic importance to farmers that their animals should breed regularly—with the possible exception of those farmers who concentrate on fattening: even they are dependent on other farmers who keep breeding stock and supply them with store animals for feeding. Females that fail to breed are described as sterile. Of the farm animals, cows and mares are liable to be completely sterile, but it is rare to find ewes and sows that are unable to breed, though they may not produce a satisfactory number of offspring. Cows that are permanently sterile do not present a serious problem, as they can be fattened and sold for beef. It is more difficult to deal with the problem that arises when animals that have hitherto produced a calf regularly fail to come on heat, or return to service after being mated. Temporary sterility of this nature may mean serious economic losses to milk producers, who must arrange the mating of their cows to ensure a regular supply of milk.

CAUSES OF STERILITY

Failure to breed in farm animals may be due to a number of different causes. There may be some deformity or injury to the generative organs, or the ovaries may fail to ripen and shed an egg, so that the female does not come into season. The animal may be in too poor condition to breed; and, in some cases, especially with animals that have been fattened for show purposes, they may be too fat for breeding. Sterility may be due to a disease such as Contagious Abortion, which results in the loss of a calf and the failure of the animal to return to service. It is not uncommon to find that the reason for failure to breed lies with the bull or other male animal concerned.

Any deformity in the female generative organs is frequently a matter of permanent sterility and the animal is disposed of. In many cases, however, the difficulty may be overcome by the technique of artificial insemination. This form of sterility is often due to the semen failing to remain in the vagina after service or failing to propel itself into the uterus and make contact with the egg shed from the ovary. With artificial insemination, it is possible to inject the semen further into the female tract and so enable fertilization to be effected.

A common cause of sterility is the failure of the ovaries to shed an egg, and it is impossible to serve the female because she does

not come on heat. After an egg has been shed, there develops on the ovary a small yellow body and, if the egg is fertilized, this remains during the period of pregnancy. In some cases, this yellow body, often referred to by its Latin name, *Corpus luteum*, persists on the ovary although the animal is not pregnant. If this happens, the ovary does not produce another egg and the animal does not come on heat. A persistent yellow body can be squeezed out from the ovary by a veterinary surgeon and the cow usually comes on heat in the course of the next two to six days. Sterility caused in this way cannot be cured by artificial insemination.

In some farm animals, especially with sheep, sterility may be due to the animal being in too poor a condition. The absence of a sufficient supply of food may mean the under-development of the reproductive organs and consequent failure to breed. There is no doubt that an animal that is in a thriving or an improving condition is more likely to breed, and this is the basis of the farm practice of "flushing the ewes." This may be done under grass or arable conditions and consists of giving them an extra supply of food for a short period before mating begins, which causes them to come on heat more quickly and increases the proportion of twins.

One common cause of sterility is that the animal is too fat. When an animal is in this condition, the reproductive organs themselves are covered with fat and the eggs from the ovaries fail to ripen properly. This is a serious matter with animals that have appeared in the show ring. These are often the best type of stock and are of good pedigree but are fattened for show purposes and afterwards fail to breed. This may be corrected by a reduction in the amount of food given to the animals and by giving them plenty of fresh air and exercise, but it may mean the loss of a whole breeding season.

Contagious Abortion is a serious disease that affects cows and, as its name implies, the disease causes the abortion, or premature birth, of the calf. It is very contagious and can be passed from one animal to another. In some cases, the disease is brought on to the farm by an animal purchased in the market. The disease may be transmitted by a bull that has previously served an infected cow. The loss of the calf is in itself serious because it means that the herd is short of a newly calved cow, and this affects the amount of milk produced from the herd. To add to the seriousness of an attack, it often proves impossible to get the animal into calf again. Service should not be attempted for at least three months after the abortion. A cow that has once been affected by the disease becomes immune, and is not infected a second time. The disease can be detected in an animal by an examination of its blood, and young heifers can be inoculated against it. As a

matter of general livestock policy, it is safer to rely on home-bred heifers to replace losses from a herd rather than run the risk of bringing disease on to the farm by buying unknown stock.

The bull or other male animal concerned, though not often suspected as a possible cause, may account for the fact that a female does not breed. A male animal may perform the act of service, but if the semen does not contain a sufficient number of strong and healthy sperm, sterility results. Bulls and other males may be sterile through age or excessive use, and a male that is too fat may be unable to produce good semen. The sterility may be due to a disease or to a structural defect of the generative organs. The potential fertility of a bull can be tested by a veterinary surgeon, who examines a drop of the semen under the microscope immediately after service. The semen should be full of active sperm moving about in the fluid. The reason for the absence of healthy sperm may be purely temporary, such as a sudden change of conditions or a prolonged period of not being used, when the semen contains a high proportion of dead sperm. If an examination of the semen shows that the male is sterile, he should not be disposed of at once, especially in the case of a valuable pedigree animal. He should be turned out to grass for a time and the semen tested again later.

Failure to observe when a female is in season is not strictly a cause of sterility but is often a reason for the failure to breed. With cows, this is specially liable to occur during the winter when they are indoors and when the period of heat may last only for a few hours. If it occurs during the night, it is missed, and even during the day it may be difficult to detect in a dark cowshed. When out of doors cows on heat display a general sense of restlessness and frequently jump on the backs of other animals or allow other animals to jump on them.

With successful cattle breeding, the factor of greatest importance is regularity of breeding, and this is of major importance to the producer of milk. In sheep and pigs, sterility, or complete failure to breed, is not common, and with these animals the number born in the litter assumes the greater importance. Twins in cattle are not regarded with favour except in beef breeds, but in sheep twinning is a definite economic advantage. The proportion of twins is likely to be higher when the ewes are in a thriving condition at the time of service. The male, though not himself capable of affecting the number of twins from his own mating, may transmit to his daughters a factor that disposes them to twinning. It is important to realize that, if rams are selected on the basis of their size alone, single rams are almost always chosen and, in time, the average twinning capacity of the flock is lowered.

With pigs, the number in a litter is of prime economic importance and a good sow should rear from 8 to 10 pigs from each litter. The number of young pigs born depends to some extent on the feeding of the sows during pregnancy, but some pigs have a tendency to produce large litters and other consistently produce small litters. The best method of maintaining a high percentage of pigs weaned from each litter is to breed only from gilts that have themselves come from sows with a high fecundity (the phrase used to describe the ability to produce large litters).

Heredity

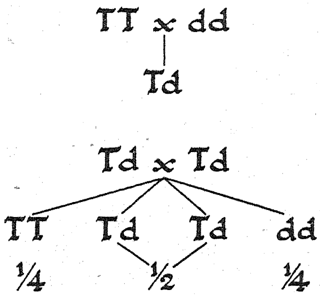
It is important to remember when dealing with the breeding and rearing of farm animals that every animal inherits a number of characteristics from its parents and that these characteristics can be influenced only to a limited degree by the conditions under which the animal is kept. On the other hand, farm animals only develop their best inborn characteristics to a maximum when kept under proper conditions. The science of heredity is known as genetics, and aims at discovering how various different characteristics are inherited.

It is a matter of common observation that like tends to beget like. No two individuals, whether animals or human beings, are exactly alike, and yet there are always strong family likenesses which bear out the general observation. It is a matter of expectation that when a red bull is mated to a red cow, the normal result is the birth of a red calf. This is true with pure-bred animals such as the Lincoln Red. The reason is that the sperm from the red bull carries with it a factor to produce red offspring, and similarly the egg from the cow has a factor for redness. But many cases occur where the mating of two animals of the same colour produces offspring of entirely different colours. To explain this, it must be assumed that, although the male and female were of a particular colour, either one or both of them carried, in the sperm or the egg, factors for the other colours that have appeared in the offspring. Mixed colours, such as roans and blue whites, are examples where the offspring show a wide variety of colouring. This may arise when a white bull is mated to a red cow, and the offspring is probably a roan calf. This calf is carrying, in its sperm if a male, and in the egg if a female, factors for redness and whiteness. The colour of its offspring would be determined by the colour factors being carried by the animal to which it is mated.

The way in which such characteristics are inherited is more easily seen in plants than in farm animals, because a greater number of the offspring can be observed. Moreover, many plants fertilize themselves, and this reduces the complication of factors introduced

by another parent. Inheritance of certain characteristics was first studied in detail by an Austrian monk named Mendel, and the mode of inheritance has been called Mendelism. He made his observations on the garden pea. He crossed a tall variety with a dwarf variety, collected the seeds, and planted them the following year. All the seeds that were planted produced tall plants, and the character for shortness seemed to have disappeared. The seed from the second-year plants was saved and sown again in the third year, and a number of dwarf plants appeared, although all the plants in the previous year had been tall. The explanation appeared to be that some of the previous year's tall plants had been carrying a factor for shortness. Mendel counted the number of dwarf plants that occurred and found that they were almost exactly one-quarter of all the plants.

In the fourth year, the seeds from the dwarf continued to be dwarf; but of the other three-quarters of the seed, some continued



A. The seeds from the plants in this generation would be carrying factors for tallness and dwarfness, but all plants would be tall in appearance.

B. When crossed, this generation gave three combinations of factors. TT, tall plants breeding true for tallness; dd, dwarf plants breeding true for dwarfness; Td, giving tall plants that carried factors for tallness and dwarfness and when crossed would segregate again in the same proportions.

FIG. 21. MENDEL'S THEORY OF INHERITANCE

to produce tall plants whilst others, which amounted to a half of the seed grown in the third year, separated out into tall and dwarf plants in the same proportion of one-quarter dwarf and three-quarters tall. Thus, a quarter of the seeds from the second generation bred true for tallness, one-quarter bred true for dwarfness, whilst the other half were carrying the factors for tallness and shortness.

The way in which the two characters were inherited is illustrated in Fig. 21. The original tall plant can be assumed to be carrying a double factor for tallness, which can be represented by the symbol TT, and the dwarf plants would then be represented by dd.

Certain characteristics in animals are inherited in the same way. All the calves born to an Aberdeen Angus bull, which is black in colour, are black regardless of the colour of the dam. But if the

black calves are mated to each other some of the offspring are black, but others are the same colour as the original dam. Some years ago an attempt to develop a new breed of cattle called the Blue Albion met with considerable difficulty in the matter of colour. Blue Albion cattle are bred by mating a Friesian and a Shorthorn, but when the offspring from this cross are mated to each other they do not breed true for colour. The appearance of unexpected colours in the breeding of animals is best explained by an understanding of the Mendelian theory of inheritance.

In the example of the inheritance of characters in peas, only two clearly defined characters were involved and are comparable to colour in animals. But there are far more characters needed to produce the ideal animal and the problem is more complex. The work of the breed societies in this country has made it possible to keep the breeding of animals more or less true to a fixed type, but the emphasis has been more on appearance and past history of the ancestors than on the present performance of the animals. The problem of breeding for performance is not capable of solution on simple Mendelian lines. If a cow that is capable of producing a high yield of milk has a calf by a bull from a low yielding strain, the milking capacity of the offspring tends to become an average between the two extremes. The character for high milk yield does not stand out and is not so clearly defined as the tallness of a plant or the coat colour of an animal.

One of the breeding problems with a dairy herd is to find the capacity of a bull to breed daughters with high milking qualities. The bull cannot be tested for milk yield but he may be carrying the factor in his sperm and he passes it on to his daughters. This cannot be judged by external appearance alone. If a bull has come from a cow that has given a high yield of milk, it is not unreasonable to assume that he possesses the factor for high milk yield. The only proof of this is the milk yield of his daughters. But this presents a further difficulty, as it is three years at least before any of his daughters has produced a calf and completed a lactation. It may be five or six years before a sufficient number of his daughters have come into milking to give a reliable indication of his powers to transmit a factor for high milk yield. For the early part of his life, a bull has to be used on the strength of his breeding history rather than on his performance, and it often happens that a bull is disposed of before his breeding qualities have been realized. He may be difficult to handle as he gets older or his appearance is poor and unpromising. One method used by some breeders to solve this problem is to use a bull in a herd for one or two years and then to sell him with an option to repurchase at some future date. The original owner can then

decide, in the light of the milk yields of the daughters, whether to bring the bull back for further use in the herd.

This method of testing bulls for their performance is known as Progeny Testing and it is now possible, with some breeds, to purchase bulls with a guaranteed progeny record. If the milk yield of cattle in this country is to be increased, it is essential that only bulls with a good progeny record should be used. The developments in the use of artificial insemination make it possible to have the full benefit from bulls with a good progeny record.

It is important to appreciate the great influence that the male animal has on the improvement of farm livestock of all descriptions. In the course of a year, the male influences a large number of offspring whilst the female is normally limited in the case of cattle to one calf a year with occasional twins, or with sheep to a maximum of three lambs a year. The qualities of a good male or the disabilities of a bad one have far more influence on the type of stock than any individual female in the herd, and great care and attention should be given to the choice of a male. With some breeds of cattle, there is a scheme known as grading-up, by which the offspring of non-pedigree cows are eligible for registration as pedigree stock after being mated for four generations with a pedigree bull. Where a policy of grading-up is to be practised, the cows must be inspected and approved as being of a suitable type for the breed, and are described as foundation cows.

One method or policy of breeding often practised with good results is known as in-breeding. This implies the mating of closely related animals, brothers with sisters or sires with their own daughters. It is possible by this means to concentrate the good points of a breed, but equally it is possible to concentrate the bad qualities. Used with discretion, close matings of this kind may lead to a great improvement in a herd, but careful watch must be kept for the development of any undesirable characters, or of any tendency towards sterility. It is only by in-breeding that a standard type of animal can be fixed.

Where in-breeding does not lead to complete sterility, it often results in a loss of constitution. As opposed to this, the crossing of two quite unrelated individuals often produces offspring with a good constitution and noted for their vigour in growth. This fact is used by farmers who breed animals only to be fattened for the production of meat. These vigorous cross-bred animals are good from a commercial point of view but they ought not to be used for further crosses as they are of mixed breeding themselves. A number of well recognized and established cross-bred animals are used for commercial purposes. With sheep there are the well known Half-breds which combine the hardiness of the mountain

sheep with the size of the grassland breeds. Large White pigs are commonly crossed with the MiddleWhite and the offspring can be used for pork or bacon. Sometimes, a cross is made between the Large White and the Large Black, because the Large Black sows make better mothers.

Sex-linkage

In poultry, there is one form of crossing of special interest, known as sex-linkage. When a Rhode Island Red cock is crossed with a Light Sussex hen, the factor for sex and the factor for colour are linked in the chickens that are hatched. The chicks that are light in colour are always cockerels and the brown-coloured chicks are females. Using this method of breeding, the producer of eggs need only rear pullets and the cockerels can be fattened and sold as table birds. The drawback to this method of crossing is that the offspring cannot themselves be used for breeding and new pure-bred stock must be used every year. Of recent years, breeds of poultry have been developed that breed true for colour but produce chicks the sexes of which can be distinguished at hatching by differences in the colour of the down.

Breeding Fallacies

There are two common beliefs about breeding that are quite unsupported by scientific facts. The first is that an impression made on the mother during pregnancy has some effect on the offspring. A common instance of this is the belief that a woman who sees a hare during the period of pregnancy will have a child born with a hare-lip. This kind of belief has been found among farmers even to the length of keeping a cow in a shed with red walls to ensure the birth of a red calf. The other persistent belief is known as telegony, which is concerned with the effect of a previous mating on a later pregnancy. There is a classic example of this belief where a mare belonging to a nobleman had been mated with a zebra and produced a foal, and a year later was mated to a pure black Arab stallion. From the second mating a foal was born with striped markings, which were assumed to be due to the previous mating. It has since been shown that this was mere coincidence and that foals bearing striped markings occasionally appear without any previous mating with a zebra. Some societies responsible for breeds of sheep will not allow lambs to be registered as pure-bred if at any time previously the ewe has been mated to a ram of another breed.

It is obvious that in the case of the animals on the farm performance is of greater importance than appearance. The policy of the show ring in this country is open to criticism in that the prizes are given on appearance, and that the animals are often so fat that

they are unable to breed subsequently. A more useful form of competitive show is based on the milk yield of cows or on the carcass of meat produced by an animal. The laying trials for poultry are another example of this type of competition. The emphasis is put on performance, and shows and competitions of this character may have a good effect on the breeding policy of farmers.

Chapter 6

THE COMPOSITION OF FEEDING-STUFFS

THE most important matter in the management of farm livestock is their feeding. It represents by far the greatest item of cost, and absorbs a large proportion of the time of the men looking after the animals. The farmer himself has to devote a considerable amount of thought and attention to planning the cropping of his farm and to the purchase of other foods to provide for the needs of his animals. To understand the problems connected with feeding, it is necessary to learn something about the composition of the feeding-stuffs available, and the functions of the different constituents in the nutrition of the animal.

No animal can exist for any length of time without food, and its requirements vary according to the age of the animal and the purpose for which it is being kept. All animals need a basic amount of food to provide for the indispensable processes of living, including breathing, the circulation of the blood, the maintenance of body temperature, and the digestive processes. Above this basic requirement, food has to provide for a number of purposes. For young growing animals, the food is needed for the development of the skeleton and muscles. Fattening animals must be fed so that they produce a saleable carcass of meat. Females used for breeding must have sufficient food to nourish their young during pregnancy and to provide a supply of milk during suckling. With dairy cows, the food must be given for the production of a surplus of milk to be sold for human consumption. The feeding of horses must provide the necessary energy for the work they are required to do.

Constituents of Food

Most of the feeding-stuffs available for farm animals are derived from plants. The constituents of plants that are of importance in feeding are starch, fibre, protein, oil, and mineral ash. These are found in varying proportions in different feeding-stuffs, and are built up in the living plant from the nutrients absorbed from the soil, and from the carbon dioxide and water combined in the leaves of the plant to form starch.

The most abundant constituent of the feeding-stuffs grown on the farm is starch, with other closely related compounds such as sugars. These compounds are known as carbohydrates and contain carbon, hydrogen, and oxygen. The amount of hydrogen and oxygen is always in the same proportion as in water, namely

two parts of hydrogen and one part of oxygen. Chemists write the formula for water as H_2O. The chemical formula for some of the simpler sugars would be written as $C_6H_{12}O_6$, and this can be described as six parts of carbon combined with six parts of water. Starch is a more complex compound which is built up from the simple sugars and contains a large number of units, each unit consisting of six parts of carbon attached to five parts of water. It is not sweet to the taste and is insoluble in cold water, but when it is digested it takes up another part of water and breaks down into simple sugars once more.

Carbohydrates are the main source of supply for the energy required by the animal. When coal is burnt in a fire it releases energy in the form of warmth, and in much the same way the starch is broken down in the body, in the presence of the oxygen taken in by breathing. This breakdown releases the energy contained in the starch, which is then available to the animal for muscular activity, and eventually appears as heat. After a period of violent physical exercise, the body gets a surplus of heat, which causes sweating, and the heat arises from the rapid oxidation: that is, the breaking down, in the presence of oxygen, of carbohydrates, and the releasing of the energy they contain. The energy needed by an animal for its vital processes, and for the purposes of working, can be derived from carbohydrates. If an animal consumes more carbohydrates than it needs, the surplus is stored in the body as fat; and if the animal should be deprived of its food, it can live for some time on the reserves of energy that it has stored in its body. Carbohydrates should be considered as the main source of energy for the needs of an animal, and may be compared with the fuel needed to keep an engine working.

Some of the carbohydrate found in feeding-stuffs is more complex than starch and is known generally as fibre. This is found more abundantly in plants as they get older. The fibre is used by the plant to strengthen its stems and leaves, and in some cases the fibre becomes almost woody in character. The straw of cereals, the tough stalks of cabbages, and the stringy parts of beans as they get older are familiar examples of the development of fibre in plants. From the point of view of nutrition, some of this fibre can be digested by farm animals, especially in the case of ruminants, whose capacious digestive system allows them to extract a fair amount of feeding-value from the fibre. But with many of the coarser feeding-stuffs, especially hay and straw, an appreciable amount of the fibre is indigestible and is disposed of in the fæces. The diet of both human beings and animals needs a proportion of indigestible fibre, partly to give a comfortable feeling of fullness, and partly to assist the action of the bowels in the elimination

of waste products and to prevent constipation. Ruminants need a diet with a fair proportion of fibre to facilitate the chewing of the cud.

The proteins found in feeding-stuffs are more complex substances and contain a percentage of nitrogen in addition to carbon, hydrogen, and oxygen. The muscles, skin, and horns of an animal are composed of protein, and the obvious function of protein in a feeding-stuff is to provide the raw material for the building up of the body. When a young animal is growing, it needs more protein in its food than is necessary for a fully grown animal, which has completed the growth of its flesh and muscle. But a fully grown animal needs a small supply of protein. During the course of muscular activity, some of the protein is broken down and must be replaced by protein from the food. Protein should therefore be regarded not only as a source of energy to the animal, but as the material needed for the growth of the body and for the replacement of worn out tissues. The need for protein is more limited than for carbohydrates, and the requirements of an animal diminish as it gets older. The animal is unable to store a surplus of protein in its body, and any surplus that it eats above the minimum requirements is broken down in the body to release what energy it contains, and the unwanted nitrogen, which has no energy value, is excreted in the urine.

Vegetable fats and oils are not abundant constituents of farm feeding-stuffs, with the exception of certain oil cakes and meals. As a food, oil is used for the purpose of supplying energy ; and though it is more complex and more difficult to break down than carbohydrates, it is capable of releasing a much higher amount of energy to the animal. It can be regarded as a valuable supplementary source of energy to that supplied from carbohydrates, but it does not assume great importance in the nutrition of farm animals, by comparison with the nutrition of human beings, whose diet normally contains a much higher proportion of fat.

All feeding-stuffs contain a small amount of mineral ash, which is the residue left if the food is burnt, and all plants contain a residue of ash that cannot be destroyed by heat. The mineral content of a food is of special importance in feeding because some parts of the animal, in particular the skeleton, contain a large amount of minerals. Bones are composed mainly of two mineral substances known as calcium, which is a constituent of lime, and phosphorus, an element used for the manuring of crops. The needs of a young growing animal for calcium and phosphorus for bone formation must be met from the food it eats. Other minerals are needed by the animal, though not in large amounts, and small quantities of iron, sodium, and chlorine must be provided in the

diet. Where there is reason to think that the food being given to an animal is deficient in minerals, they can be added to the ration or fed separately as a mineral mixture. Salt licks are frequently provided for animals as a source of minerals, especially of sodium and chlorine, which, when combined, give the substance known as common salt.

The constituents of feeding-stuffs so far described can be found on analysis. There are certain other essential substances known as vitamins. They are present in minute quantities, but their absence from a diet results in serious disorders in the animal. The vitamins that are found in feeding-stuffs have been classified either on the basis of the type of food in which they are found or according to the disorders that arise in their absence. Up to the present many vitamins have been discovered, the five main groups being known as Vitamins A, B, C, D, and E respectively.

Vitamin A is sometimes described as the fat-soluble vitamin and is found in milk, butter, and cod liver oil. It is formed primarily from a colouring matter called carotene, which is present in all green plants. If the diet of a dairy cow is low or deficient in carotene, the milk and butter from the cow is low in Vitamin A. It is very noticeable that butter is a much deeper yellow colour in summer than in winter ; this is because in summer a high proportion of the food is fresh green grass. A shortage of Vitamin A in the food of a young animal slows up growth and development, whilst in more mature animals its absence causes greater liability to disease.

There are several vitamins grouped together as Vitamin B, and they are found principally in cereal grains, especially in the outer layers, which form the bran. There is a certain amount of Vitamin B in milk. A shortage of Vitamin B leads to a number of nervous disorders ; but as cereals form a considerable part of the food of farm animals, there is not a great risk of a shortage of this vitamin. The same is true of Vitamin C, which is present in all roots and green plants. In former days, sailors suffered severely from a disease called scurvy when on long voyages with no fresh vegetables, and it has now been proved that the absence of Vitamin C in their diet caused the disease. Guinea pigs develop scurvy if kept for more than three weeks on food that has no Vitamin C in it. As practically all farm animals, with the possible exception in certain cases of pigs, get a part of their food in a fresh green state, a shortage is hardly ever likely to occur.

Vitamin D is closely associated with Vitamin A, and is found in cod liver oil. It is also produced in the skin of animals when exposed to sunlight. It is of special importance in the formation of teeth and bones, and in human beings, especially children, the

absence of this vitamin leads to rickets, the bones becoming soft and misshapen. Vitamin E is one of the more recently discovered vitamins. It is found in green plants, and its absence leads to sterility in animals.

Although the vitamins are of great importance in human nutrition, it is not common to find farm animals suffering from a shortage. It is only when animals are kept under unnatural conditions that vitamin deficiencies may occur. There is a danger of this happening when pigs are kept continually in a sty with no sunlight, or when poultry are kept indoors under intensive conditions. In both cases, the risk is a shortage of Vitamins A and D, and these can be provided by feeding cod liver oil. There is also a possibility of a shortage of Vitamins A and D in the milk from dairy cows in winter, and, to prevent this, a small quantity of cod liver oil may be used. The deficiency is not likely to occur if the ration includes good hay, silage, or kale; all of which should have a good carotene content.

Classification of Feeding-stuffs

There is a wide variety of foods available for feeding to farm livestock, and the feeding-stuffs are usually classified under the four main headings of green fodders, succulent foods, roughages, or coarse fodders, and concentrated foods.

Green Fodders

Green fodders are the natural foods of most farm animals. Included under this heading are pasture grass and the fodder crops that may be used to supplement the pastures during the summer, or cut green for winter feeding, or made into silage. In the summer, the basis of feeding farm animals is grazing. The grass grows rapidly in the spring, and in most parts of this country there is ample grazing in May and June. Grass is much more nutritious when it is young than when it gets older, and it is important to ensure that enough animals are put on the fields in the early months to eat down the herbage and prevent the grass from becoming too coarse and fibrous. As the summer progresses, particularly in the southern and eastern parts of the country, the quality of the grazing is apt to decline after June unless there is enough rain to maintain a steady growth. It then becomes necessary to supplement the grazing with other green forage crops, such as lucerne, clovers, and vetches, which are cut green and carted out to the pastures. The usual practice is to take hay from these fodder crops in June, and to use the second growth, or aftermath, for feeding green. This process is known as green soiling.

Maize is frequently grown for the special purpose of being fed green in August and September. Although it cannot be sown until early May, it grows rapidly and after the end of July yields a large bulk of green fodder. Maize is not able to withstand frosts, and the fodder must be used by the end of September or it is damaged by early autumn frost. Some green fodder crops are grown more especially for use in autumn and winter. One of the most valuable crops in this respect is narrow stem kale, which produces a high yield of fodder and can be used until the end of December or early January, and even later with some varieties. There are also varieties of cabbage that can be used in the same way.

Included under the heading of green fodders are the many different forms of silage that are made during the summer and autumn, and used during the winter. Crops preserved in this way have a special value as winter foods because if the silage is properly made it retains a proportion of the carotene that was present in the green crop. It is also possible to cut grass when it is very young and most nutritious, and to dry it artificially for use in winter.

The general characteristic of the green fodders is their relatively high moisture content, which amounts, on an average, in green plants to 80 per cent. The remainder of the plant contains protein, carbohydrate, and ash, and a small amount of fibre ; and they are reasonably well balanced foods. Apart from silage and dried young grass, the green fodders are fed in a fresh state and approximate to the one important natural food of farm animals, which is grass.

Succulent Foods

The group known as succulent foods includes the various roots and tubers that are grown on the farm for livestock. These have a higher water content than the green fodders, amounting to nearly 90 per cent, and they have a small percentage of indigestible fibre. They are grown mainly for use in winter and can be safely stored without any important change in their composition or feeding value. The root crops most widely grown are mangolds, turnips and swedes, and kohl rabi. As a feeding-stuff, they provide the animal mainly with carbohydrate, in the form of sugar or starch. Turnips, swedes and kohl rabi are fed at any time during the autumn and winter, but mangolds must be stored in a clamp until after Christmas before they can be fed to stock. If they are fed earlier than this, they cause the animals to scour. Although the average water content of root crops is 90 per cent, the yield from an acre is high, and, when compared with other crops on the basis of the yield of dry matter, they are the most

productive crops on the farm. Other root crops used for feeding to stock are carrots, potatoes, and parsnips.

Sugar beet pulp should be included with this group ; for, although it is rarely fed in a succulent condition, it is the product of a succulent crop, and its composition is comparable with that of the dry matter of root crops. It is the by-product after the extraction of the sugar from the roots, and as a feeding-stuff it is very rich in carbohydrate. One pound of sugar beet pulp is equal in feeding value to one pound of oats, and this gives some indication of the high feeding value of the dry matter of root crops.

Roughages

Hay and straw are the principal foods classified as roughages, or coarse fodders. They are bulky in character and contain a high proportion of indigestible fibre. Wheat straw and barley straw are both very fibrous, and for this reason are more frequently used for bedding than for feeding. The straw is often given to animals so that they may pick out the more nutritious bits, and then tread the remainder into farmyard manure. Oat straw is higher in feeding value, because the crop is generally cut while it is still fairly green, and the straw does not beome so coarse and fibrous. Hay is the most important feeding-stuff in this group, and it forms the staple winter food of horses and cattle, and is often used for sheep. The quality and feeding value of hay is not constant. Meadow hay varies considerably in feeding value according to the age at which it was cut, and the conditions under which it was made. If the hay is left too long before cutting, the plant becomes more fibrous ; and if the hay is badly made, it loses a considerable amount of its nutrients. Hay from a seeds ley, from lucerne, or from sainfoin, differs in composition, especially in respect of protein. Lucerne hay may have nearly 10 per cent of digestible protein, while second quality meadow hay may contain only half that amount.

Concentrated Foods

The feeding-stuffs dealt with so far have been the whole, or nearly the whole, of the plant concerned, and are generally produced on the farm. The group known as the concentrated foods are derived from the seeds or grain of plants, and may have been grown on the farm or purchased from the corn merchant. These feeding-stuffs may be further classified as cereal grains, leguminous grains, by-products from cereal grains, and oil seed cakes and meals, and they are considered under these headings.

The three cereal grains most commonly grown on the farm are wheat, barley, and oats. Wheat and barley are similar in compo-

sition and have a high starch, or carbohydrate, content, but are low in protein and fibre. Oats are a better balanced cereal and contain a higher percentage of protein and oil. They are usually fed without the outer husk being removed, and this results in a higher fibre content, which makes them more easily masticated. Oats are a safe feed for almost all farm animals, though pigs are unable to consume large quantities because of the high fibre content. Wheat and barley are essentially fattening or energy-giving foods, and if they are used for young stock, or for animals producing milk, must be supplemented by other foods containing more protein and ash. Maize is a cereal grain that does not grow and ripen in this country, but large quantities are imported. As a feeding-stuff, it is more unbalanced than wheat and barley in respect of protein and ash ; but when used with other foods, it is most valuable for use with fattening animals. As a group, the cereal grains are lacking in protein, and must be supplemented by home-grown or purchased foods to make good this deficiency.

The only home-grown source of foods rich in protein that can be used to supplement the cereals are the leguminous grains. The crops grown for this purpose are beans and peas. By comparison with the cereal grains, they have a lower content of carbohydrate, but the percentage of protein is high, amounting to 25 per cent in beans, and a little less in peas. Beans and peas are ground or crushed into a meal and may be used for almost every type of livestock. These foods should not form more than a small proportion of the ration and should be used only to make up a shortage of protein.

The by-products from cereal grains are an important source of feeding-stuffs for farm animals, particularly the by-products that come from the milling of wheat, sometimes referred to as millers' offals. These arise from the way in which wheat is milled to produce pure white flour, which is the most popular form of wheat flour. To produce this, the outer layers of the wheat grain must be removed, as well as the small germ, which would have grown into a new plant if the seed had been allowed to germinate. The outside layer is sold as bran, which is flaky in character and has a high fibre content. It is not of a high feeding value, but it possesses certain valuable laxative properties and may be used for both horses and cattle. The second layer of the wheat grain is separated from the bran and sold as weatings, and a still finer grade of weatings may be bought under the name of super-fine weatings. They form a well-balanced food containing a fair percentage of protein and oil as well as carbohydrate. Large quantities of weatings are used by farmers for the fattening of pigs, and they are included in the rations of both fattening and milking

cattle. These by-products are produced not only from the wheat grown at home but from any wheat that is imported as grain and milled in this country, and they are an important item in the feeding of farm animals.

The brewing industry has a by-product that is used by farmers for stock feeding. After the production of malt from the grains of barley, the residue is sold to farmers as brewers' grains. These are most frequently sold in a wet condition, and, owing to the danger of fermentation, their use is limited to those farmers who are near enough to the brewery to fetch the grains and use them immediately. In some cases, the grains are dried before sale, and in this condition they can be transported a greater distance.

There are many different oil seed cakes and meals on the market that are used for the feeding of farm animals. They are manufactured from the residue of a number of oil-bearing seeds that are imported into this country for the sake of the oil they contain. The oil is extracted from the seeds and is used in the manufacture of soap, glycerine, and margarine. One method of extracting the oil is to crush the seeds between powerful presses, which squeeze out the oil. With this method of manufacture an appreciable amount of oil is left in the residue, which adds to its feeding value. Another process for the removal of the oil is to use a liquid in which the oil will dissolve, and this method of extraction is more thorough and leaves less oil in the residue. From either method of manufacture, the oil seeds, after extraction, are used for stock feeding. These foods are bought as oil cakes where the oil has been removed by pressure, or as extracted meals where a solvent has been used.

These residues are generally rich in protein and are used to supplement the home-grown feeding-stuffs, which, with the exception of beans and peas, are low in protein content. Only small quantities need be added to the rations of farm animals to bring the rations up to the amount of protein required ; and as these cakes are expensive to buy, care should be taken not to use them extravagantly.

Linseed cake is perhaps the most popular of these cakes and is greatly valued by stock feeders. It contains nearly 30 per cent of protein ; in addition it has valuable laxative properties, and is sometimes added to a ration that otherwise might have a constipating effect. It is often used by stock feeders in the final stages of fattening, and a small proportion of linseed cake gives the animals a sleek coat and a well finished appearance, generally referred to as "bloom." Linseed cake is not used to any extent for pigs, as it gives an oily texture to the bacon fat.

Ground nut cake is made from ground nuts imported into this

country, the nuts sometimes being sold as monkey nuts or pea nuts. There are two grades of ground nut cake, one of which is made from the nuts and their shells, and the other from the nuts after the shells have been removed. The first of these grades is sold under the name of undecorticated ground nut cake, and this contains a higher percentage of fibre than a cake made from the nuts alone, which is sold as decorticated. The protein content of the decorticated cake is very high and may amount to as much as 47 per cent. Only small quantities of a food so rich in protein are needed in the ration of any farm animal.

Cotton cake is also sold as undecorticated or decorticated. The decorticated grade is high in protein, and the undecorticated cake has a special value because of a property it has for the prevention of scouring. It is commonly used in a ration containing a high proportion of roots, which might cause scouring. It is also used as a binding food for animals when first turned out to grass, when they are very liable to scour.

Palm kernel cake is another valuable feeding-stuff, but contains only 17 per cent of protein, which is lower than most of the oil cakes. Animals at first dislike its taste, and it must be introduced gradually into a ration. Once the animals have become accustomed to it, there is no further difficulty in using it. Other cakes in general use are coco-nut cake and soya bean cake. Coco-nut cake contains about 20 per cent of protein, which is also low by comparison with other cakes, but it is useful for all kinds of stock, and, when ground to a meal, can be used for pigs. Soya bean cake contains more than 40 per cent protein, has a slight laxative action, and can be used for all classes of stock.

The cakes and meals that have been described are those most commonly met with, but others can sometimes be purchased. It is essential that the buyer of any of these cakes and meals should obtain from the seller an analysis showing what the cake contains.

There are on the market a number of feeding-stuffs sold as compound cakes and bearing the name of the manufacturer concerned. These may contain a variety of constituents and are often manufactured for a specific purpose, such as dairy cake or calf-rearing food. In every case, the farmer can obtain the analysis of the compound so that he may know what he is buying. The proprietary cakes have the great advantage of simplicity for the rationing of farm animals, and the correct feeding of a dairy cow is easily achieved by using the quantities recommended by the manufacturer. This form of rationing is very nearly fool-proof, and within the compass of any farmer. These compounds are very palatable, and the manufacturers use in the mixture many valuable foodstuffs that would be refused by the stock if fed alone.

They are often manufactured in the form of small nuts, which are easy and economical to handle. It must be remembered that whereas the oil seed cakes and meals are the by-products from the oil industry, the compound cakes are specially manufactured and may for that reason be more expensive. The farmer who aims at using a high proportion of home-grown cereals may find it necessary to buy concentrates rich in protein to balance the foods he has produced, instead of these compound cakes or dairy nuts.

There are a number of miscellaneous substances used for animal feeding and probably the most important of these is fish meal. Only high-grade white fish meal should be used for feeding purposes, and by law the percentage of oil, which is the constituent most likely to give rise to a taint, must not exceed 6 per cent, and the salt content must not be more than 4 per cent. Fish meal is very rich in protein, containing over 50 per cent, and it has a special value because of its high mineral content, which may amount to 20 per cent. It is a valuable supplement to the rations of young animals, the protein being used for the building up of muscle, and the minerals for the development of the bones. The use of fish meal for older animals is not to be recommended, partly because it is unnecessary, but mainly because it is liable to produce unpleasant taints in the flesh or milk of the animals, which makes them unsuitable for human consumption. The amount needed in a ration is small because of its high protein content, and 10 per cent is the usual proportion in the ration of young pigs. A pig at this early age would not consume more than $2\frac{1}{2}$ lb. of food a day, and the amount of fish meal required is only $\frac{1}{4}$ lb. a day. Other foods of a similar character that are rich in protein are meat meal and blood meal, and they should be used only in small quantities.

To sum up the position with regard to the foodstuffs that are available to the farmer for his animals, it will be seen that the foods grown in this country are bulky in character though rich in vitamins, and that the concentrates are generally rich in carbohydrates, such as starch and sugar. On the whole, home-grown foods are deficient in protein and oil. These deficiencies are made good by using the different forms of oil seed cakes and meals, which are particularly rich in protein and oil. These foods are used as a supplement and help the farmer to make the maximum use of his home-grown feeding stuffs.

CHAPTER 7

RATIONING OF FARM ANIMALS

THE rationing of farm animals may be defined as the allocation to each animal, or to a group of animals, of the correct amount and the proper type of food, taking into account the requirements for maintenance of life, and for growth and production of meat or milk. Rationing is of great importance from the economic point of view, as feeding represents by far the greatest single item of cost in livestock management, and wasteful feeding means a serious loss of profits. Rationing is important to the animals themselves if they are to remain healthy and productive. Under-feeding results in a loss of condition and poor returns, but over-feeding is equally undesirable and may lead to digestive disorders, and in some cases to a falling off of production. It is essential that a proper balance is achieved in a ration between the constituents that provide energy, such as carbohydrates, and those that provide the body building materials, the proteins. The composition of the feeding-stuffs available to the farmer has been discussed in the previous chapter, but before a ration can be calculated it is necessary to learn the amount and type of food required by an animal for different purposes. These requirements have been worked out in terms of the energy-giving and body-building constituents required, and the rations for farm animals must contain the necessary amount of carbohydrate and protein, in a daily allowance of food that is within the capacity of the appetite of the animal concerned.

DIGESTIBLE NUTRIENTS

The total amounts of carbohydrates, protein, and oil in a feeding-stuff can be ascertained by a chemical analysis, but such an analysis is only of limited value in finding how much of the food should be used. The important factor to be determined is the proportions of the different constituents that can be digested by the animal. This is done by a feeding experiment on a living animal. The animal is kept in a special crate, which is designed so that the fæces and urine from the animal may be collected separately. A sample of the food to be used is first analysed to determine its content of carbohydrates, fibre, oil, and protein. The animal is then fed on a constant amount of the food for a period of fourteen days, and the fæces are collected and analysed. The difference between the amounts of the various constituents in the food and the amounts found in the fæces represents the

proportion abstracted by the animal in the course of the passage of the food through the digestive tract. This difference is referred to as the digestible nutrients, and it is on the basis of the content of digestible nutrients that a ration is drawn up for an animal.

Starch Equivalent

The range of composition of the many feeding-stuffs available is so wide that it becomes necessary to have a common basis, or standard, on which a comparison can be made of one food with another. One of the earliest standards to be adopted was to compare all feeding-stuffs with hay. This was a simple basis of comparison, but it had a very serious disadvantage, because hay itself is variable in composition. The modern method of comparison is to calculate the value of feeding-stuffs in terms of starch, which is a substance of constant composition. Every feeding-stuff is expressed in its relation to the feeding value of starch, and this figure is known as the starch equivalent of a feeding-stuff. The method was first worked out by a German scientist named Kellner, who calculated his figures in two ways: one by a method of direct feeding to an experimental animal, the other by a calculation on the figures based on analysis.

In his feeding experiment, Kellner used a bullock that was receiving a ration sufficient to maintain it in a condition where it was neither gaining nor losing weight. He added to the ration a daily allowance of 2 lb. of pure starch, and as a result of this addition the animal put on ½ lb. of fat a day. He did other feeding experiments using pure protein and pure fat, and his results showed that 2 lb. of protein gave less increase of fat than 2 lb. of starch, whilst 2 lb. of fat gave considerably more. He was thus able to compare the relative capacity of starch, protein, and fat in the production of fat in an animal's body. The relative capacities of starch and protein were in the proportion of 1 : ·94, and those of starch and fat were approximately as 1 : 2, depending on the nature of the fat content of the food. From these ratios he was able to calculate the theoretical starch equivalent of a feeding-stuff by multiplying the percentages of digestible carbohydrate by 1, of protein by ·94, and of fat or oil by 2, thus expressing each constituent in terms of starch and relating the feeding-stuff to pure starch. This theoretical figure was checked by feeding a known quantity to an animal on a maintenance ration and calculating its capacity for the formation of fat by comparison with pure starch. Kellner found in his experiments that foods were never as efficient in practice as they should have been according to his calculations. He found that the difference was greater with foods with a high fibre content, due to the greater difficulty of

digesting a fibrous food, which made it less effective as a source of energy.

Tables are available giving the Starch Equivalent of all the feeding-stuffs likely to be met with on a farm, the most comprehensive tables being published in a bulletin issued by the Ministry of Agriculture called *Rations for Livestock*. The starch equivalent of a feeding-stuff is usually given as a percentage, the value of 100 lb. of a food being expressed as the number of pounds of pure starch that provide the same feeding value. Thus the Starch Equivalent of linseed cake is expressed as 74, which means that 100 lb. of linseed cake has the same energy value for feeding purposes as 74 lb. of pure starch.

Protein Equivalent

In calculating the starch equivalent of a feeding-stuff, all the digestible constituents are included because, although protein is primarily a body-building food, it is also used by the animal as a source of energy. By comparison with carbohydrates and fat, the energy derived from protein is wasteful, and, when used for its energy, protein leaves nitrogenous waste products, which have to be disposed of by the kidneys. The function of protein is the building up of muscles in the young animal and the repair of worn-out muscles in both the younger and the older animal. Animals require a certain minimum amount of digestible protein for these purposes, and the ration should not contain more than this amount of protein ; the balance of the energy requirements should be given in the form of carbohydrates and oils.

Feeding-stuffs may contain a number of nitrogenous compounds that are less complex than proteins but have a nutritive value. Such compounds are present in appreciable amounts in green fodders and roots, which are fed before the plants have completed the manufacture of proteins. For feeding purposes, these are assumed to have a value equal to about half that of a pure protein ; and in the analysis of a feeding-stuff, the percentage of pure protein added to half the percentage of other nitrogenous products is referred to as the protein equivalent.

Computation of Rations

To calculate a ration, the starch equivalent and protein equivalent of the foods must be known, and the requirements of the animal for different purposes have been worked out on the same basis. The amounts required must be contained in a quantity of food that can be eaten by an animal in a day. There must be sufficient bulk of food to satisfy the animal's appetite, and this bulk must contain the necessary starch equivalent and digestible

protein. Thus, a ration for an animal must be calculated to agree with the three following points: it must contain a sufficient amount of starch equivalent to meet the total requirements of the animal; a proportion of the total starch equivalent must be in the form of digestible protein, or its equivalent; the ration must contain a sufficient amount of dry matter to satisfy the animal's appetite, but not more than the animal is capable of eating.

TABLE 14

THE AVERAGE COMPOSITION IN RESPECT OF PERCENTAGE OF DRY MATTER, STARCH EQUIVALENT, AND PROTEIN EQUIVALENT IN THE FEEDING-STUFFS IN FIG. 22.

FEEDING-STUFF	DRY MATTER %	STARCH EQUIVALENT PER 100 LB.	PROTEIN EQUIVALENT PER 100 LB.
Green Fodders			
Pasture Grass	20	11	2·1
Marrow Stem Kale	14	9	1·35
Lucerne	24	9	2·45
Succulents			
Mangolds	13	7	0·4
Swedes	11	7	0·7
Roughages			
Oat Straw	86	20	1·0
Wheat Straw	86	13	0·1
Meadow Hay (Good)	86	37	4·5
Concentrates			
Wheat	87	72	10·0
Oats	87	60	8·0
Beans	86	66	20·0
Bran	87	43	10·0
Weatings	87	58	12·0
Linseed Cake	89	74	25·0
Decorticated Ground Nut Cake..	90	73	41·0
Fish Meal	87	59	53·0

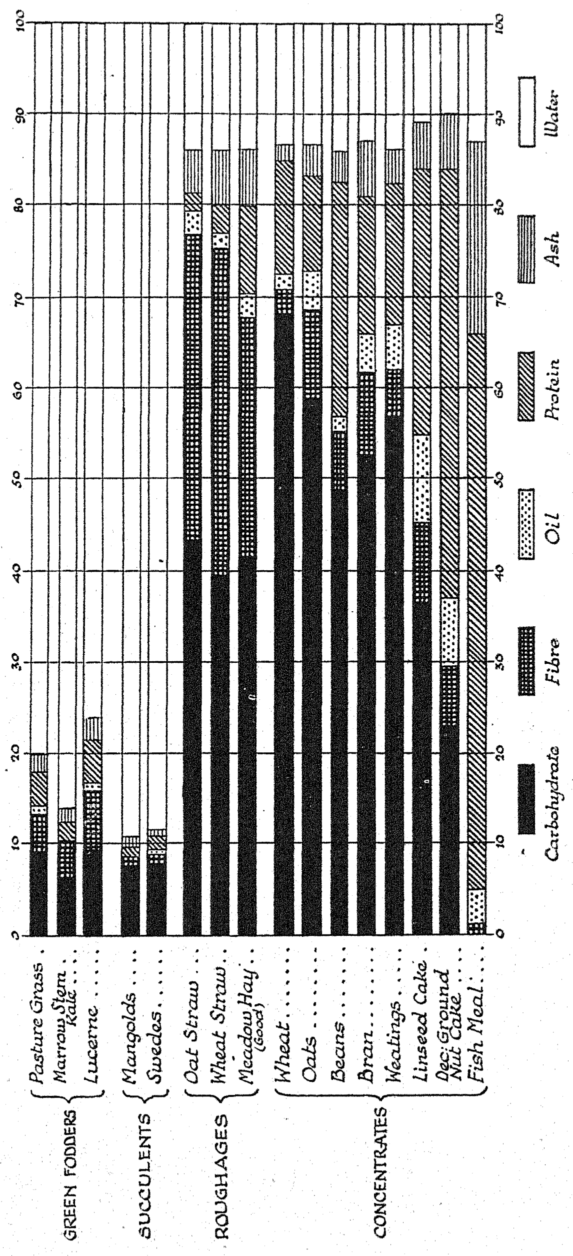


FIG. 22. COMPOSITION OF FEEDING-STUFFS IN TABLE 14

When calculating a ration, the part needed for the processes of life is referred to as the maintenance ration, and the part that provides for growth and milk yield is known as the production ration. An animal needs a basic amount of starch equivalent in the maintenance ration to enable it to live and move about, and for standing. There must also be a definite amount of digestible protein for the replacement of wear and tear in the muscles. The starch equivalent and digestible protein given in excess of the requirements of maintenance are available for productive purposes, and these have definite requirements in respect of starch equivalent and digestible protein.

There are a number of other considerations to be taken into account when choosing a ration for farm livestock. It is essential that the food is palatable and readily eaten by stock. Some foods are more palatable than others, and it is often difficult to get stock to eat such foods as palm kernel cake, hay that is slightly musty in flavour, or wheat straw, which is coarse and tasteless. Molasses are sometimes mixed with rations to increase their palatability. It is important not to make sudden changes in a ration, but to introduce different foods gradually. Some feeding-stuffs are naturally laxative, whilst others have a binding effect, and in computing a ration a suitable combination of the two types of food should be used to balance the ration in this respect. Care must be taken to ensure that no foods are used that may have undesirable effects on the quality of produce. Any food with a strong flavour, as for example fish meal, may cause a taint in milk or in flesh. Foods that cause the formation of fat with a soft and oily texture should be avoided when fattening animals for disposal as meat.

Rations for Beef Cattle

The maintenance requirements of cattle depend on the weight of the animal, and the following table gives the daily requirements for cattle of different weights in terms of starch equivalent and protein equivalent. As has been stated, the ration must conform to the appetite of the animal, which increases with its size, and the table includes the daily consumption of dry matter at different weights.

Animals weighing less than 5 cwt. are calves or very young stock, and their feeding is more of an art than a science so far as any precise method of rationing is concerned. Young animals should be fed liberally but not extravagantly, and the ration should be rich in protein and minerals. It should be noted from the table that, while the animal's requirements for starch equivalent increase as it gets older, its need for protein remains constant after it has reached a weight of 7 cwt.

TABLE 15. MAINTENANCE RATIONS

LIVE WEIGHT OF ANIMAL cwt.	DAILY CONSUMPTION OF DRY MATTER lb.	MAINTENANCE REQUIREMENTS	
		STARCH EQUIVALENT lb.	PROTEIN EQUIVALENT lb.
5	$14\frac{1}{2}$	4	$1\frac{1}{4}$
6	17	$4\frac{1}{2}$	$1\frac{1}{4}$
7	19	5	$1\frac{1}{2}$
8	$20\frac{1}{2}$	$5\frac{1}{2}$	$1\frac{1}{2}$
9	22	6	$1\frac{1}{2}$
10	$23\frac{1}{2}$	$6\frac{1}{2}$	$1\frac{1}{2}$
11	25	7	$1\frac{1}{2}$
12	$26\frac{1}{2}$	$7\frac{1}{2}$	$1\frac{1}{2}$

A bullock that is receiving a ration according to the table will neither gain nor lose weight, and a comparatively simple ration would provide all that was necessary. For example, 20 lb. of meadow hay would contain sufficient starch equivalent for the maintenance of a 12 cwt. cow, though she would feel rather hungry owing to the lack of bulk, but this could be made good by straw. Very few cattle, with the possible exception of a mature stock bull, are kept on a farm to remain at a constant weight. With beef cattle, additional food is given to enable them to increase in weight and put on fat and so produce a good carcass of meat. Cattle to be fattened for beef go through a relatively long store period, when they are growing but not getting fat, and they are usually over two years of age before they are finished for the butcher. The amount of live weight gain of an animal during the store period is about 1 lb. a day, and experiments have shown that no additional protein need be fed for this, but that the production ration should consist only of starch equivalent. The amount required for each 1 lb. a day of live weight gain varies with the age of the animal according to the following table :—

TABLE 16. PRODUCTION REQUIREMENTS FOR FATTENING ANIMALS

Animals under 2 years old	$2—2\frac{1}{4}$ lb. of Starch Equivalent
Animals about 2 years old	$2\frac{1}{4}—2\frac{1}{2}$ lb. of Starch Equivalent
Animals over 2 years old	$2\frac{1}{2}—3$ lb. of Starch Equivalent
Fat animals over 2 years old	4 lb. of Starch Equivalent

It is important to note how rapidly the consumption of starch equivalent increases as the animal gets fatter, and this shows that it is not economic to keep animals until they are in a very fat condition.

The computation of rations for beef production can best be illustrated by working out a few typical examples :—

EXAMPLE 1. *A ration for a store animal of 5 cwt., which is kept in yards during the winter and is expected to increase in weight at the rate of 1 lb. a day.*

From Tables 15 and 16 (page 191) it is seen that an animal of this weight has a daily appetite of 14½ lb. of dry matter, that its maintenance requirements are 4 lb. of starch equivalent and 1¼ lb. of protein equivalent, and that for the live weight gain desired it should receive a further 2 lb. of starch equivalent a day. The ration should contain a total of 6 lb. of starch equivalent and 1¼ lb. of protein equivalent, and should contain about 14½ lb. of dry matter in bulk. An animal at this age would be expected to consume a fair amount of such foods as hay, oat straw, and roots, and as it is young and has a small appetite, the ration will need some concentrated food.

Assume the following foods are available, with their average composition :—

	DRY MATTER %	STARCH EQUIVALENT PER 100 LB.	PROTEIN EQUIVALENT PER 100 LB.
Meadow Hay	86	37	4·5
Swedes	11	7	0·7
Oat Straw	86	20	1·0
Oats	87	60	8·0
Decorticated Ground Nut Cake ..	90	73	41·0
Beans	86	66	20·0

A suitable daily ration could be made up as follows :—

	DRY MATTER lb.	STARCH EQUIVALENT lb.	PROTEIN EQUIVALENT lb.
5 lb. Meadow Hay	4·3	1·85	0·22
7 lb. Oat Straw	6·0	1·4	0·075
20 lb. Swedes	2·2	1·4	0·14
2 lb. Decorticated Ground Nut Cake	1·8	1·46	0·82
1 lb. Crushed Oats	0·87	0·6	0·08
Total	15·17	6·71	1·335

This ration is slightly excessive in dry matter and also in starch equivalent, but in practice each animal eats a greater or less amount of oat straw according to its appetite, and this adjusts the consumption of dry matter to individual requirements.

EXAMPLE 2. *A ration to fatten a bullock of 10 cwt. over 2 years of age at a rate of 2 lb. a day.*

An animal of this weight has a daily appetite of 23½ lb. of dry matter, and a maintenance requirement of 6½ lb. of starch equivalent, and 1½ lb. of protein equivalent. For production, an animal needs 2½ lb. of starch equivalent for each lb. of live weight gain ; and for the rate of gain desired, a production ration of 5 lb. starch equivalent must be given. The ration should therefore contain a total of 11½ lb. of starch equivalent and 1½ lb. of protein equivalent, and should approximate to 23½ lb. in bulk. Using a selection of the home grown foods given for Example 1, a ration could be made up as follows :—

	DRY MATTER lb.	STARCH EQUIVALENT lb.	PROTEIN EQUIVALENT lb.
12 lb. Meadow Hay	10·3	4·4	0·54
6 lb. Oat Straw	5·16	1·2	0·06
50 lb. Swedes	4·4	2·8	0·28
3 lb. Crushed Oats..	2·5	1·8	0·24
2 lb. Beans	1·7	1·3	0·40
Total	24·06	11·5	1·52

As the animal increases in weight, it requires additional amounts of concentrated foods to provide the increased starch equivalent needed for each pound of live weight gain until it receives a total production ration of 6 lb. of starch equivalent.

EXAMPLE 3. *Rate of liveweight gain of an animal weighing 10 cwt. being fattened on grass in summer.*

An animal of this weight has a daily appetite of 23½ lb. of dry matter, and if it ate this quantity of grass it would get 13 lb. of starch equivalent and 3 lb. of protein equivalent. For maintenance it requires 6½ lb. of starch equivalent and 1½ lb. of protein, but as the animal has to move about to obtain its food, it needs a further 1 lb. of starch equivalent to provide the necessary energy. The total maintenance requirement is 7½ lb. of starch equivalent leaving a surplus of 5 lb. of starch equivalent for productive purposes. This should be sufficient for a daily increase of 2 lb. of

live weight gain, and the animal should fatten for the butcher without being given any supplementary concentrates. It is of interest to note that when an animal is grazing a pasture of good quality young grass, it is consuming considerably more than its minimum requirements of protein.

Rations for Milk Production

In the rationing of dairy cows, provision has to be made for the maintenance of the animal and for the production of milk. For maintenance, a dairy cow is rationed on the basis of her weight according to the following table.

TABLE 17

MAINTENANCE RATIONS FOR DAIRY COWS

LIVE WEIGHT OF ANIMAL	DAILY CONSUMPTION OF DRY MATTER	MAINTENANCE REQUIREMENTS	
		STARCH EQUIVALENT	PROTEIN EQUIVALENT
cwt.	lb.	lb.	lb.
8	22	5·5	0·65
10	23½	6·5	0·70
12	25	7·5	0·75
14	26½	8·25	0·80

The food necessary for the production of milk is added to these maintenance requirements, and is calculated on the basis of the daily milk yield in gallons. Experiments have shown that, to produce one gallon of milk, most breeds of dairy cow require a minimum of 2½ lb. of starch equivalent and ·5 lb. of protein equivalent. For Jersey and Guernsey cows, a larger allowance has to be given, amounting to 3 lb. of starch equivalent, and ·7 lb. of protein equivalent.

The most practical method of rationing a herd of dairy cows is to calculate a standard ration to be given to each animal to provide for its maintenance and the production of one gallon of milk. The additional amounts needed for the cows giving more than one gallon a day are fed in the form of concentrated food at the time of milking. The bulky foods of the ration, such as the hay and roots, are most conveniently given to the animals in the yard. Each animal will adjust its daily intake of food according to its appetite. This is made possible by giving the different kinds of

food in the order of concentrates at milking time, followed by the succulent foods and finishing with hay. The animals receiving the largest allowances of concentrates for high milk yield eat correspondingly less of the bulky foods. For animals giving very high yields of milk, special individual feeding in a separate box would be necessary.

EXAMPLE 4. *Rations for dairy cows weighing 10 cwt. and giving one gallon of milk a day and over.*

It is assumed that the following home-grown foods are available, with respective compositions :—

	DRY MATTER %	STARCH EQUIVALENT PER 100 LB.	PROTEIN EQUIVALENT PER 100 LB.
Meadow Hay	86	37	4·5
Marrow Stem Kale	14	9	1·35
Beans	86	66	20·0
Oats	87	60	8·0

To provide for maintenance and for the production ration for one gallon of milk for cows weighing 10 cwt., the ration for each cow would have to contain starch equivalent and protein equivalent as follows :—

	STARCH EQUIVALENT lb.	PROTEIN EQUIVALENT lb.
Maintenance Ration.. ..	6·5	0·7
Production for 1 gallon of milk	2·5	0·5
Total	9·0	1·2

This could be given in a ration made up of hay and kale in the following proportions :—

	DRY MATTER lb.	STARCH EQUIVALENT lb.	PROTEIN EQUIVALENT lb.
15 lb. Meadow Hay..	12·9	5·5	0·675
45 lb. Kale	6·3	4·0	0·6
Total	19·2	9·5	1·275

Cows that are not yielding more than a gallon of milk would have access to straw to supply their daily appetite for dry matter. For cows giving a yield of more than one gallon a day, a suitable ration for each additional gallon could be made up of 2 lb. of beans and 2 lb. of oats, which have the following composition :—

	DRY MATTER lb.	STARCH EQUIVALENT lb.	PROTEIN EQUIVALENT lb.
2 lb. Beans	1·7	1·3	0·4
2 lb. Oats	1·7	1·2	0·16
Total	3·4	2·5	0·56

Thus a cow giving a daily yield of 2 gallons would receive 4 lb. of this mixture, and one giving 3 gallons would receive 8 lb. The higher yielding animals would require less of the bulky food, though in practice it is found that a cow giving a high milk yield often has an appetite larger for its weight that is shown in the tables. It is of interest to note that adequate rations for dairy cows can be supplied from home-grown foods, though as the winter progresses, it would be necessary to substitute mangolds for kale. If home-grown concentrates are not available, many suitable production rations can be worked out, using a mixture of home-grown foods and purchased concentrates, or depending entirely on purchased foods. It is in connection with the rationing of dairy cows that proprietary mixtures of dairy cakes or nuts can be conveniently used as a supplement to home-grown bulky foods.

EXAMPLE 5. *Summer rations for a dairy cow weighing 12 cwt. on a pasture of average quality.*

An animal of this weight eats grass containing about 25 lb. of dry matter a day, which provides about 14 lb. of starch equivalent and 3 lb. of protein equivalent (Table 14). For maintenance, it needs 7·5 lb. of starch equivalent plus a further 1 lb. for the energy spent on walking about, leaving about 5 lb. of starch equivalent for the production of milk. After making allowances for a maintenance requirement of ·75 lb. of protein, there are 2·25 lb. of protein equivalent, which is more than sufficient, with the 5 lb. of starch equivalent, for producing a daily milk yield of 2 gallons. It would only be necessary to feed supplementary concentrates to cows giving more than 2 gallons a day, and as there is a surplus of protein the supplement need only provide starch equivalent. On a very good pasture that is properly grazed

a cow weighing 12 cwt. should consume enough grass to produce 4 gallons of milk a day, but there are few pastures that would continue to give such good grazing except in April and May.

In rationing dairy cows, it is advisable, when the yield of milk is on the increase, to feed the cow for one gallon above her yield to encourage the animal to reach her maximum production. As the milk yield begins to fall, the ration should be adjusted, as over-feeding depresses the yield more rapidly than is necessary. Unlimited feeding to a cow with only the capacity for a low milk yield depresses the yield still further and encourages the animal to put on fat instead of producing milk.

The accurate rationing of the cows in a dairy herd depends on the keeping of individual milk records and the adjustment of rations to the yield. The bulky foods and the roots can be weighed out for the herd as a whole, but the concentrates should be fed individually, preferably at the time of milking, when each cow can be given its particular ration. The mixture of concentrates should be made up in bulk, and the cowman provided with a measure that holds the right amount for each gallon. It is an easy matter for the man in charge of the cows to give each animal so many measures of the concentrates according to the number of gallons she is yielding.

The Rationing of Sheep

Unlike cattle, sheep are rarely kept in houses, and most of their food is consumed as it is growing, in the form of either grass, root crops, or fodder crops. There are certain periods of the year when it may be necessary to supplement their green food with hay and concentrates. Ewes that are suckling their lambs, and lambs that are being fattened on roots in the winter need additional food. With mountain and grassland sheep, supplementary food may be needed in the winter months.

When ewes have had their lambs, they are given additional food in the form of hay and concentrates to supplement any arable folding crops that may be available. Owing to the small size of a sheep compared with a bullock, it is more convenient to calculate their rations on a weekly instead of a daily basis. A ewe that is suckling its lambs consumes from 35 to 40 lb. of dry matter a week. The weekly consumption of roots or kale would be of the order of 150 lb., with a dry matter content of 22 lb., and the balance has to be provided as hay and concentrates. Expressed in terms of starch equivalent and protein equivalent, the weekly requirements of a suckling ewe are 21 lb. of starch equivalent and at least 3·5 lb. of protein equivalent. The kale or roots provide about 13 lb. of starch equivalent and 2 lb. of protein equivalent,

and the ration would have to be supplemented as follows :—

	DRY MATTER lb.	STARCH EQUIVALENT lb.	PROTEIN EQUIVALENT lb.
12 lb. Meadow Hay..	10·3	4·4	0·54
1½ lb. Decorticated Ground Nut Cake	1·35	1·1	0·63
5 lb. Crushed Oats	4·3	3·0	0·4
	15·95	8·5	1·57
150 lb. Kale	22·00	13·2	2·0
Total	37·95	21·7	3·57

Sheep that are being fattened on roots in winter need supplementary food if they are to fatten quickly. A hogget ready for fattening would weigh about 80 lb. and its weekly appetite would be 21 lb. of dry matter. In order to increase in weight at a rate of 2½ lb. a week, a fattening hogget requires 11·5 lb. of starch equivalent and 1·75 lb. of protein equivalent. The weekly consumption of roots is approximately 100 lb., which provides 14 lb. of dry matter containing, in the case of kale, about 9 lb. of starch equivalent and 1·35 lb. of protein equivalent. Supplementary foods would be fed as follows :—

	DRY MATTER lb.	STARCH EQUIVALENT lb.	PROTEIN EQUIVALENT lb.
5 lb. Seeds Hay	4·3	1·5	0·25
2 lb. Crushed Oats	1·7	1·2	0·16
	6·0	2·7	0·4
100 lb. Kale	14·0	9·0	1·35
Total	20·0	11·7	1·76

In practice, concentrated foods are not often fed to sheep, except in the case of ewes with their lambs, or when lambs are to be fattened very rapidly. Lambs are frequently fattened on roots alone, though they require a longer period before they are ready for the butcher. In calculating the acreage of roots needed by sheep, the following standards can be used. :—

100 ewes and lambs will consume 1 acre of roots in 14 days.
100 lambs will consume 1 acre of roots in 19 or 20 days.

The Rationing of Pigs

The pig has a digestive system which differs from that of the ruminants, and is unable to consume and utilize a ration with a high percentage of fibre. Rations for pigs are composed mainly of cereals, cereal by-products such as weatings, and a small proportion of a food with a high protein content to make up for the deficiency of protein in cereals. By comparison with cattle and sheep, pigs put on weight very rapidly, and to provide for this rapid growth, the ration must supply adequate amounts of protein and minerals.

The maintenance and production requirements of pigs have been calculated in terms of starch equivalent and protein equivalent. But as the rations for pigs are practically constant from the time of weaning to maturity, it is simpler to calculate the ration in terms of pounds of meal. The object in feeding pigs is to provide a ration large enough for the animals to achieve their maximum rate of live weight increase, and to avoid over-feeding, which is not only wasteful, but may lead to digestive disorders.

In order to be able to calculate a ration for pigs, it is necessary to know the daily appetite of pigs at different ages, the quantity of meal required for maintenance, and the quantity required for each lb. of live weight gain. These data are given in the following table, which has been compiled from *Rations for Livestock* (H.M.S.O.) :—

TABLE 15

DAILY APPETITE OF PIGS AT DIFFERENT AGES

WEIGHT OF PIG lb.	DAILY APPETITE lb.	MEAL REQUIRED FOR MAINTENANCE lb.	MEAL REQUIRED PER LB. LIVE WEIGHT GAIN lb.	DAILY REQUIREMENT OF PROTEIN EQUIVALENT lb.
50	2—2·5	1·5	0·7	0·3
100	4—4·5	2·9	1·0	0·5
150	6	3·3	1·5	0·6
200	7	3·6	2·0	0·6

A practical guide to the amount of food required by a pig is that it consumes 1 lb. of food for every month of its age up to a maximum of 7 lb. a day.

If a pig is fed with a properly balanced ration to the limit of its appetite, the difference between its maintenance requirement and its total consumption is available for growth, and from this, the rate of live weight gain can be calculated. A pig weighing

50 lb. eats about 2 lb. of meal a day, of which 1·5 lb. are needed for maintenance, leaving ·5 lb. of meal for growth. At that age a pig needs ·7 lb. of meal for every 1 lb. of live weight gain, so that it should put on weight at the rate of about ·75 lb. a day. At a live weight of 150 lb., the appetite has increased to 6 lb. of meal a day, of which 3·3 lb. are needed for maintenance, and the remaining 2·7 lb. of meal provide sufficient food for a daily increase of about 1·75 lb.

Barley meal forms the major part of the rations for pigs, and this is fed with weatings in the proportion of 2 parts of barley meal to 1 part of weatings. This mixture is deficient both in protein and minerals, and the deficiency is best made good by the addition of fish meal, which is rich in both these constituents. The proportion of fish meal should not exceed one-tenth of the whole ration, and a simple, practical way of making up such a ration is to mix 7 stones of barley meal, $3\frac{1}{2}$ stones of weatings, and 1 stone of fish meal. At a live weight of 50 lb., the pigs should receive each day 2 lb. a head, and the daily amount should be increased as the animals get older. As the animals approach the weights at which they may be sold as pork, which is 100 lb., or as bacon, at 200 lb., the fish meal should be left out of the ration, as the strong flavour of the fish meal is liable to taint the flesh and make it unpalatable for human consumption. It is possible to avoid the use of fish meal altogether by using a high protein cake or meal as a supplement to the barley meal and weatings, and giving the pigs free access to a mineral mixture. Pigs should receive a small amount of green food each day, and in the early stages of growth cod liver oil may be added to the ration to provide Vitamin D. This is of particular importance when pigs are kept in houses that do not get any direct sunlight.

The standard ration given above is capable of many variations according to the foods available. A quarter of the ration may be composed of maize meal, ground wheat, ground rice, or rice meal. Potatoes are often used for the feeding of pigs, but should always be cooked before feeding, and 4 lb. of cooked potatoes are equivalent in feeding value to 1 lb. of barley meal. Separated milk is sometimes available for pig feeding, and is used for the mixing of meal into a gruel. Separated milk has a fairly high mineral content, and when it is used as part of the ration the amount of fish meal can be reduced to 5 per cent. Pigs are rarely kept singly on a farm, and when a number are fed together it is important to have a sufficient number of troughs, or the animals waste a considerable amount of energy in struggling to get their food. This activity reduces the rate at which the animals increase in weight.

The Rationing of Working Horses

The feeding of horses must provide both a maintenance and a production ration; though in this case, the production ration is needed to give the energy for the performing of work. A typical winter maintenance ration for a heavy farm horse would consist of from 16 to 20 lb. of meadow hay a day, and to this would be added a ration of crushed oats, the amount varying according to the amount of work being done. For medium work, the daily ration of oats is 12 lb., and this is increased in times of heavy work and reduced when less work is being done. In summer, grazing and some fresh green fodder take the place of hay. When the corn ration is increased in times of heavy work, such as in the spring or during harvest, a part of the corn ration may consist of cracked beans, giving a corn ration of 12 lb. of oats and 2 lb. of beans. The best guide to the rationing of horses is the appearance of the animal, and a horse which is being under-fed for the work it is doing soon shows its loss of condition.

The Rationing of Poultry

In principle, the feeding of poultry is based upon the requirements of each bird for maintenance, growth and for egg production or fattening, and the ration must provide sufficient quantities of starch equivalent and protein equivalent to meet these requirements.

In the early stages of growth, chicks need a diet that is rich in protein and ash, and provided the ration is suitable in this respect it can be fed to the limit of the chick's appetite. During this early stage, the ration should contain a proportion of such foods as dried skim milk and meat or fish meal, these having a high protein and ash content. As the birds get older, the amount of food consumed is calculated according to the weight of the birds and not on their age. In using this basis, allowance is made for the difference in weight of birds of the same age but of different breeds. A young fowl weighing 1 lb. consumes approximately 2 ounces of food a day, whilst a fully-grown bird, weighing from 3-4 lb. consumes on the average about 4 ounces of food. By comparison with dairy cows, poultry need more than twice as much food for every pound of body weight.

The rations for laying birds must provide sufficient calcium for the formation of the shell of the egg, and the amount of protein required is relatively high. For egg production, the proportion of protein to starch equivalent is approximately one-third, whereas for the production of a gallon of milk the proportion of protein is only one-fifth. The additional quantities of protein needed by poultry can be provided by using foods of animal origin that

would not be suitable for dairy stock. Most of the laying mashes provided for poultry consist of a mixture of starchy foods such as maize, weatings, and ground oats, with a protein rich food such as fish meal or meat meal. The remainder of the ration usually consists of maize, wheat, and oats fed as whole grain.

In the feeding of poultry, attention must be paid to the provision of grit, which is needed for the mastication of food in the gizzard ; oyster shell grit is often given as a supplementary source of calcium. When poultry are kept on an intensive system, their diet may be deficient in Vitamin D unless cod liver oil is included. Under more natural conditions, where birds get access to fresh green food and are exposed to sunlight, cod liver oil is not normally needed. When feeding birds whose eggs are to be used for hatching, the ration must be drawn up to include foods that ensure an adequate reserve of vitamins in the eggs for the use of the chicks when hatched. Valuable foods for this purpose are dried skim milk and lucerne, or alfalfa meal. For fattening purposes, a ration should consist mainly of starchy foods and need not contain a very large amount of protein.

Chapter 8

ANIMAL HYGIENE

ALTHOUGH feeding is one of the most important aspects of livestock management, there are a number of other principles to be observed if a satisfactory system of management is to be achieved. These may be generally described as animal hygiene, and they include all the steps that must be taken to keep farm animals in a good state of health, as well as the treatment to be given to animals that have contracted disease. The treatment of diseases is primarily a matter for a qualified veterinary surgeon, but it is the responsibility of farmers to see that, so far as possible, their animals are kept in clean and healthy conditions, and so make them less susceptible, less liable to contract disease.

Farmers have a further responsibility in the matter of hygiene because the greater part of the products from their animals is consumed as human food. Every precaution must be taken to prevent human food from becoming contaminated with the micro-organisms of disease. This aspect is of special importance in the production of milk, which is a product easily infected and which forms an ideal medium in which the organisms of disease readily multiply.

Water Supply

The supply of water is a most important consideration in the management of livestock. Animals cannot live without water, and die from lack of water in a very short time, whereas they could exist without food for a much longer period. Water is also needed in large quantities for cleaning purposes, especially for the sheds and utensils required for milk production. Apart from the needs of the farm animals, a clean and wholesome supply of water is required for the domestic use of the farmer and for the workmen who live in the cottages on the farm.

In all towns, and in many large villages, even the smallest houses and cottages are provided with water from a tap, the water being piped from a central reservoir or store under the control of a water company. Farms are often remote from such supplies of water ; though where water is supplied in this way, it is the most satisfactory method. It gives water of a standard cleanliness and of sufficient pressure for the needs of the farmhouse and buildings, and is not likely to fail completely in a time of drought.

It may be an ideal at which to aim that every farm and its buildings and all rural dwellings should have a piped water supply,

but it may be many years before it is achieved. Many farms are so remote that it may never be possible to link them with a central piped supply.

In the absence of a piped supply, a farm is dependent on one or other of the following sources of water : deep wells, shallow wells, springs, streams and rivers, rain-water. A well consists of a hole which is sunk into the ground and lined with bricks or some other material. The hole must be deep enough to reach an underground supply of water, and the water collects in a sump at the bottom of the well and is pumped to the surface. Before the invention of the pump, the common method of raising water from a well was by a bucket at the end of a chain or rope which was wound up by a windlass.

The depth of a well depends on the local geology, and the conditions under which the boring of a well is likely to prove satisfactory are that, at some reasonable depth below an impervious layer of clay, there is a porous layer of sandstone or chalk in which the underground water is collected. Where there is no such porous layer, the well is sunk into the ground and water from the surrounding soil collects at the bottom and the well acts as a kind of underground storage tank. In the case of a shallow well of this type, the amount of water collected depends on the local rainfall : it cannot be fed from underground supplies. In times of drought, a well of this kind is almost certain to dry out.

Springs are also dependent upon local conditions of geology. They are caused by the accumulation of water along a porous layer of rock to such an extent that the water is forced out at the surface. Supplies of water from springs are liable to fail in times of drought.

Streams and rivers are somewhat obvious sources of water, and it invariably seems to happen that the stream is at a much lower level than the premises for which the water is needed. To raise the water from the stream, some form of pump must be used. There is an automatic device known as a hydraulic ram, which uses the pressure of the water against two valves to develop sufficient power to lift the water to the height required.

Most farms have a number of tanks or troughs in which the rain-water falling on the roofs of the buildings is collected. In remote districts, this may be the principal source of supply. It is unreliable because it depends entirely upon local weather conditions. It is no uncommon sight to see rain-water troughs overflowing in winter and dry and empty in summer.

As water falls in the form of rain, it is relatively clean and pure, though it may have a small amount of gases from the air dissolved in it. As the water passes through the soil, it collects a certain

amount of organic matter, such as bits of leaves and plants, and in this condition the water may be dangerous to use. Water taken from a shallow well or from a stream may contain a considerable amount of sediment. It is most important to prevent any drainage water from manure heaps from getting into a well or stream which is used as a supply of water. As water passes into the deeper layers of the soil, the organic matter it contains is removed, and water obtained from a deep well or from a deep-seated spring is clean and safe to use.

The water needed by the animals for drinking may be provided in open troughs in the farm yard, but care must be taken to keep the troughs clean. In many stables and cowsheds, particularly the latter, there are special automatic drinking bowls in front of each animal, and water is constantly available. The animal in this way consumes as much water as it requires. Drinking-bowls should be cleaned out regularly to make sure that no particles of stale food are left in them to cause infection. If automatic drinking-bowls are used and there is no water-main supply, it is necessary to install some form of storage tank at a height above that of the buildings into which water from a well or stream may be pumped. This gives the pressure of water needed to enable the bowls to function, and pressure of water is also required for household purposes and for washing-down cowsheds.

An adequate supply of drinking-water must be provided for animals that are grazing. Some fields are naturally provided with a running stream and this is by far the most satisfactory system of watering. It is advisable, in such cases, to build a special drinking-place so that the animals do not damage the banks of the stream. Where no stream is available, drinking-troughs must be provided, and, where possible, water should be taken to them in pipes. Some form of ball valve can be used to make sure that the trough is kept constantly full, but does not overflow. Where no piped supply is available, or when the piped supply fails, water has to be carted to the troughs, and in a dry summer this is both troublesome and expensive.

It frequently happens that the only source of water for grazing animals is a shallow surface pond. This is not a reliable source of water as the pond is liable to dry out in summer. It is not very hygienic, as the water is apt to become contaminated by the droppings from the animals using it.

The consumption of water on a farm may amount to a very considerable quantity. For drinking purposes, a horse needs about 8 gallons a day, but the consumption of cows is much higher. An average for a cow in milk is from 16 to 20 gallons a day, though a heavy milker might consume up to 40 gallons. Fattening cattle

and store cattle consume about 10 gallons of water daily. The amount of water that an animal drinks depends to some extent upon the proportion of roots and other succulent foods in the ration. The needs of sheep vary according to the type of food they are consuming, but a ewe that is suckling lambs may consume from 3 to 4 gallons of water a day. Pigs often receive their food as a wet mash, but in addition, may drink from 2 to 3 gallons of water.

The consumption of water for cleaning purposes varies according to many different circumstances, but for a cowshed in which 15 cows are housed, at least 30 gallons are needed for washing it down. About half a gallon is required for washing each cow before milking. Large quantities are required to pass through the milk cooler, and, though it is difficult to give any definite figure for this, it is probably not less than $2\frac{1}{2}$ gallons for each cow in the herd. It seems that at least 5 gallons of water a day are wanted for each cow in the herd for purposes other than drinking. The amount of water required every year for each cow in milk is of the order of 12,000 gallons, and farmers should not undertake the production of milk on a farm that is inadequately supplied with water. One common source of wastage of water is the milk cooler, which is often allowed to run for an excessive amount of time. On farms where the supply of water is limited, water from the cooler should be collected and used for other purposes. Perhaps the only time when farmers become conscious of the amount of water used is during a period of drought when it has to be carted ; but an adequate supply of water at all seasons is an essential on any farm.

The Housing of Farm Animals

Most farm animals spend a large proportion of the year out of doors, and under these conditions the liability to disease is much reduced. But, for the winter months, it is necessary to provide the animals with some form of shelter in order that they may continue their growth and fattening, or their production of milk, at an economic level. Animals must be housed for the convenience of feeding them during winter. The only animals on the farm that are rarely housed are sheep, and they require shelter only at the time of lambing, especially when the lambs are born early in the year.

The fact that farm animals have to be kept in yards and buildings brings with it problems of hygiene and sanitation, and these are mainly affected by the design of the buildings concerned. The first consideration in farm buildings is that they should provide adequate warmth and shelter for the animals, and this is

linked with the problem of ventilation. Nature has provided horses and cattle with skins that offer a good protection against cold, and it is probably shelter that is required of farm buildings rather than a high temperature. The artificial heating of farm buildings is not needed in this country, but stock keepers frequently aim at getting their buildings too warm, and this is done by reducing the ventilation. Nothing is more conducive to the contraction of disease and to the loss of vigour in animals than to keep them in a warm and stuffy atmosphere.

Although proper ventilation is essential, it does not follow that farm animals, any more than human beings, should be allowed to stand or lie in draughty buildings. A balance between warmth and ventilation should be achieved, and this is best done by having warm material for floors, a plentiful supply of bedding, and an efficient system of ventilation.

It is not proposed to go into the details of the different substances and materials used in the construction of farm buildings, or to discuss the various artistic and æsthetic considerations affecting design. These are matters that vary from one district to another, and should be the concern of the builder and architect, though a farmer, when considering the erection of new buildings, should not ignore this aspect of the problem. Pleasant, well designed, and well built farm buildings give added enjoyment to the work on a farm, but the prime considerations, when judging any system of buildings, must be the effect they have on the animals that occupy them, and the ease with which the work of the stockmen can be done in them.

There appears to be no definite opinion at the present time as to the most suitable material for the floors of buildings for animals. Whatever material is chosen, the floor should, for hygienic reasons, be non-porous so that it does not absorb the urine from the animals. The floor should be easy to clean, it should not have a surface on which the animals might slip, and it should be warm and comfortable. Moreover, the floor should be durable and capable of withstanding hard wear. Cement concrete is probably the most satisfactory material for flooring from many points of view, and, though it has the reputation of being cold and damp, this can be minimized if the concrete is laid on a layer of stones or broken bricks about four inches thick. The surface can be grooved slightly to prevent slipping. Most of the materials that give a warmer floor are expensive for use in farm buildings, though floors made of rubber slabs, and bricks of cork and pitch, have been used in piggeries. For yards and loose boxes, where generous amounts of bedding straw can be provided, a floor of rammed chalk or clunch gives satisfactory results.

Apart from the milking-shed, where straw is not used to any extent except perhaps in the dunging channel, the comfort of farm animals in buildings is greatly increased by the use of suitable bedding material in adequate quantities. Material to be used for the bedding of farm animals should be clean, dry, free from smells, and capable of absorbing a considerable amount of moisture. The most suitable bedding material available on the farm is wheat straw, which absorbs from two to three times its own weight of moisture, and, when carted out of the sheds and rotted down, makes excellent farmyard manure. Oat and barley straw may be used for bedding, but barley straw is the least satisfactory, as it is short and not very absorbent, while the presence of the awns from the barley grains causes irritation to the animals. Peat moss is an excellent bedding material because it is extremely absorbent, and is convenient to use in stables in towns where straw is not readily available. The peat moss can be bought in bales and is more easily transported than straw, but the manure made with peat moss is inferior to that made with straw.

The ventilation of farm buildings is another aspect of the problem that does not appear to have been seriously worked out, and about which there is no recognized body of opinion. There are a large number of cowsheds and stables with small windows that cannot be opened, and the buildings are dark and smelly and have no proper system of ventilation. When animals are in a building, they are continually using up the supply of oxygen and breathing out carbon dioxide. The aim in ventilation should be to change the air a sufficient number of times every hour so that the carbon dioxide does not accumulate and foul the air in the building.

There are two natural principles that assist in the proper ventilation of a building. The first is that warm air charged with products of breathing rises to the top of a building. Secondly, the movement of air outside the building, which is caused by the wind, assists in extracting the impure air. The methods used for ventilation are many and varied, but in general they consist of some form of inlet at from two to four feet from ground level, and some opening at the roof from which the air can escape from the building. The inlets may be simple in construction, and consist of a number of drain pipes let into the wall, or a space left by the removal of a brick and the insertion of a grating. There are more elaborate forms of inlet, which consist of an opening to the outside at one level, and a shaft inside the wall, which opens into the building at a higher level. This form of ventilation avoids draughts and gives the incoming air an upward motion.

The opening in the roof may be a permanently open ridge, with

a special form of tile built over it to prevent rain coming through into the building. Some buildings have roof windows that can be opened or shut as desired, or there may be a structure built along the ridge with a number of sloping boards or louvres. In all cases, the principle is the same. As the wind passes over the ridge, it sets up a suction that draws the impure air through the ventilator.

The problem of ventilation is affected to some extent by the amount of space provided for each animal. A small building with several animals in it needs more efficient and quicker ventilation than a higher, loftier building accommodating the same number of animals. On farms where Accredited or any other recognized grade of milk is being produced, the appropriate Local Authority lays down a certain minimum cubic content of air space for each animal. The usual minimum space required is 800 cubic feet per cow, and this is the equivalent of a room 10 feet long, 8 feet wide, and 10 feet high. With this amount of space the system of ventilation should change the air five times in every hour. The same minimum air space is required for horses and fattening cattle; but in calculating the space, any height above 14 feet, such as would be found in a very lofty building, must be left out of the calculation. Pigs require a minimum air space of 200 cubic feet for each animal.

The lighting of farm buildings is another matter to which attention should be paid, and the minimum lighting for stables and cowsheds is considered to be three square feet of window for each animal. There is no doubt of the added convenience of working in well-lighted stables and cowsheds. In the latter, it is important that the light should be at its best on the hind quarters of the animals, where the milking is done, and some form of roof lighting is the most satisfactory for this purpose. An excessive amount of window space in farm buildings should be avoided, as this increases the difficulty of keeping the animals warm.

Farm animals dispose of their fæces and urine in the buildings where they stand, and this adds a complication to the problem of keeping the buildings in a sanitary condition. In milking-sheds, great care has to be taken to prevent any contamination of the milk from the fæces, and this is kept to a minimum by providing a dunging channel behind the animals. The length of the standing for the cows must be planned so that it is long enough to enable the animals to lie with comfort, and short enough to make certain that the dung and urine fall into the dunging channel. The length of the standing should be not less than 4 ft. 9 in. and not more than 5 ft. 3 in., and depends to some extent on the breed of cow being kept. The standing should have a slight slope to the dunging

channel, and the dunging channel should be from 1 ft. 6 in. to 2 ft. wide, and about 6 in. deep to prevent an undue amount of splashing. The system of drainage from a milking-shed must be efficient and provide for the removal of the water used to clean down the floors. Straw should be placed in the dunging channel to absorb the urine. The general cleanliness and sanitary condition of a milking-shed are greatly improved if the walls have a smooth surface which can be washed down. A rough surface encourages dust and dirt to collect on the walls.

Pigs have a reputation of being dirty animals, but it is often the conditions in which they are kept that cause them to be dirty. In a modern pig house, a dunging passage is provided at the back of the pen where the pigs lie, and they use this to prevent their pens and their bedding from being fouled by dung and urine.

The way in which the various farm buildings are arranged, and their lay-out, are matters that affect the management of livestock in two ways. Firstly, the lay-out should be planned to give the opportunity of using labour in the most economical manner, and secondly, the lay-out should be considered from the point of view of hygiene. These two aspects may not fit well with each other. It is obviously economical in labour to have the food store within easy reach of the milking-shed, but the dust that may get into the milking shed from the food store is unhygienic. In designing a lay-out for farm buildings, attention should be paid to both these aspects ; and other factors, such as the direction of the prevailing wind, or the ease of access for lorries delivering food to the farm, should also be taken into account.

The most suitable lay-out for buildings for any farm can only be decided by local considerations. So far as the position of the milking-shed is concerned, there are four important points needing special attention in planning. The lay-out must provide a route by which the cows come to and from the shed and the pastures, a route for the transport of the milk from the shed to the cooling and bottling rooms and thence off the farm, a route for the disposal of manure, and, lastly, a route for the carting of food for the animals. So far as possible, these four routes should be quite independent, thus reducing to a minimum the chances of contamination of the milk from the food and dung of the animals. Many farm buildings fall short of the ideal in these respects, largely because the buildings were erected for one purpose and have been adapted for another. Much labour and expense could be saved if, in adapting old buildings for other purposes, proper attention were paid to the planning of the different departments. It is important to find out what are the local bye-laws with regard to buildings, so that any alterations that are made comply with them.

A number of precautions must be taken by the farm workers for reasons of hygiene, especially when they are engaged on the production and handling of milk. With all classes of farm livestock, cleanliness in the feeding-troughs is essential for preventing sources of infection. In the milking-sheds, all the cows should be washed before milking to remove any dirt attached to them. The milkers should wear a clean white smock and cap, and should wash their hands, using a disinfectant soap. Milking should always be done with dry hands. All the buckets and churns should be not only clean but sterilized, and the only satisfactory method of sterilizing utensils is to put them in a steam sterilizing chest, where the heat kills any bacteria that are present. Where milking machines are used, the cleaning of the pipes presents a special problem, and it may be necessary to pass a solution of some disinfectant through them. Ordinary disinfectants, such as carbolic preparations, cannot be used, as they would leave a taint in the pipes, which would be picked up by the milk as it later went through. Special solutions have to be used, which clean the pipes but do not taint them, and they are usually made up of sodium hypochlorite.

It must never be forgotten that milk is very easily contaminated from a number of different sources, and that it is an ideal substance for the growth and multiplication of bacteria, especially when it is at the natural temperature of milking. The reason for the immediate cooling of milk, necessary in both winter and summer, is that at a low temperature any bacteria that may be present in the milk are not so liable to increase in number. Too much care and attention cannot be paid to the problem of keeping milk clean and wholesome. If this is done, there are fewer losses to the farmers through milk becoming sour and unsaleable, and less risk to the consumer of drinking milk that is carrying the germs of disease.

Measures against Disease

The greatest risk that the livestock farmer has to face is that of disease among his animals, and the annual losses in this country through animal diseases amount to many millions of pounds. Every stock farmer should be aware of the ways in which diseases may be contracted and how they may spread, so that he can take all the precautions within his power to prevent disease breaking out, and do what is possible to prevent its spread.

It is necessary, first of all, to understand the ways in which diseases are carried. They may be classified into two main groups: non-infectious diseases, which are usually caused by some disorder of a part of the animal's body, and infectious diseases, which are caused by the entry into the body of a specific germ or microbe.

Examples of non-infectious diseases are colic in horses, which is due to bad feeding causing an inflammation of the colon, and milk fever in cows, which occurs after calving, caused by a disturbance in the udder, which sets up a form of paralysis. In neither case is there any danger of the disease being passed on to another animal. The more serious diseases are caused by the entry into the body of bacteria, viruses, and small parasites. The infectious diseases can be further classified into those that are passed from one animal to another, when they are known as contagious, and those which are non-contagious. Tuberculosis, foot and mouth disease, contagious abortion, and sheep scab are highly contagious and spread rapidly and dangerously from one animal to another. Lockjaw, or tetanus, is caused by a bacterium, but the disease is not passed from one animal to another.

The ways in which animals contract disease are many and varied. Sickness may be caused by an infection arising from the food or bedding of the animal, or the disease organism may be brought on to the farm on the boots and clothing of the farmer or his workers. Other diseases arise from the drinking of contaminated water, and most of the diseases caused by small parasites, such as worms, come from an infected pasture and are frequently due to the overstocking of the field by the same type of animal. The most likely cause of infection is from another animal, and this may happen when an animal is brought on to a farm and is carrying a disease. Some cases of infection have been traced to contact between animals over a fence dividing one farm from another. Cuts and wounds offer a ready source of entry for bacteria causing disease, and should be treated with disinfectants, or, where possible, covered with bandages.

The importance of a clean water supply has already been emphasized, and much can be done to keep down infection by due attention to this matter. The possible infection that may be brought on to a farm can be minimized by placing a small dish of disinfectant at the entrance to the yard, or to each of the houses, in which the farmer and the workmen disinfect their boots. This is a wise and necessary precaution when there is an outbreak of disease in the neighbourhood. Sheds and buildings should be regularly washed down with a good disinfectant. Straw that has been brought on to a farm as packing material should never be used for bedding, but should be burnt. A very likely source of infection is the feeding of household swill to pigs; to avoid this the swill should always be cooked before feeding.

Sheep and pigs are susceptible to attacks from internal parasites, usually in the form of some kind of worm. Infection is most commonly by way of the mouth, and when sheep or pigs are kept too

long on the same ground they are almost certain to become infected. The parasites may not prove fatal to the animal, but they cause unthriftiness and general loss of condition. The effects of these attacks can be considerably reduced by dosing the animals to clear the digestive tract of the worms, and by proper attention to the way in which the fields are grazed. For pigs, removal to fresh ground is necessary at fairly frequent intervals. Land is often described as being "sheep sick" because of the danger of the sheep grazing on it becoming infected with parasites.

Care of Sick Animals

The first essential in the treatment of an animal that has been attacked by disease is to isolate it. At least one loose box on the farm should be kept for this purpose. The sick animal should be put into it, mainly to guard against the danger of other animals on the farm becoming infected should the disease prove to be contagious. Even if the disease turns out to be non-contagious, the animal needs special care and feeding, and this is best done when the animal is by itself. Unless the farmer is certain as to the disease from which the animal is suffering, he should obtain the services of a qualified veterinary surgeon, who will diagnose the disease and prescribe the correct treatment.

Disease is frequently brought on to a farm by animals purchased in the open market, and there is always the danger that the purchased animal may be a carrier of a disease though not obviously suffering from it at the time. It is a wise precaution to keep newly purchased stock isolated for a few days in case there should be any disease among them that might infect the other animals on the farm. When a single animal is purchased, as in the case of a dairy cow, she should remain in the isolation box for a day or two. It is most important that boxes used for the care and isolation of sick animals should be thoroughly disinfected every time after being used.

There are some diseases against which precautions can be taken by the inoculation of the animal, in the same way as human beings can be inoculated against diphtheria, typhoid, and many other serious diseases. The effect of an inoculation is similar to the events that take place in the body when it is attacked by disease. When the bacterium or virus causing the disease enters the body, the blood stream immediately attempts to counteract the effect of the poisons set up in the body, and develops substances that will destroy the bacteria and their poisons. This is done by the formation of anti-toxins, which counteract the poisons, or toxins, in the blood stream. When an animal is inoculated, it is given a very mild form of the disease, but sufficient to encourage the

formation of anti-toxins, which remain in the blood and act as a resistant against a more serious attack of the disease. Some diseases, after they have attacked an animal, can be cured by the injection of an anti-toxin. Anti-toxins are often made by infecting a rabbit or a guinea pig with the disease and extracting the anti-toxin that is manufactured in its blood. The diseases against which inoculation is most frequently practised with farm animals are Contagious Abortion in cows and Swine Erysipelas in pigs. Dogs can be inoculated against distemper.

In the case of certain dangerous diseases that might spread rapidly from one farm to a whole neighbourhood, the Government have adopted special measures for their control, in order to reduce the serious losses that might be incurred by stock owners. Diseases that are controlled in this way are known as Scheduled or Notifiable Diseases, and it is the duty of every stock owner to report any suspected cases to the local policeman. The object of this procedure is to eradicate the disease from the country, and this has been successfully done in the case of some of the diseases concerned. The diseases still likely to be met with and that must be reported are Anthrax, Foot and Mouth Disease, Parasitic Mange of Horses, Sheep Scab, and Swine Fever. When an outbreak of any of these diseases is confirmed, strict regulations are enforced to prevent their spread. In most cases, the infected animals, and in the case of some, all animals on the farm, whether infected or not, have to be slaughtered and their carcasses burnt, or disposed of under the direction of a Government inspector. In the case of an outbreak of Foot and Mouth Disease the farmer is compensated by the Government for the loss of his animals. The farm is isolated and the movement of the type of stock concerned is strictly controlled. When there is an outbreak of Foot and Mouth Disease, control of the movement of stock is imposed within a radius of 15 miles from the farm where the outbreak occurred.

In order to lessen the chances of an outbreak of Sheep Scab, there are official regulations requiring that every summer sheep must be dipped at least once, and in some districts twice, to kill the mites that cause the disease. Dipping takes place in early summer after the sheep have been sheared. The dip is a poisonous preparation, and the basis is usually some form of arsenic. In addition to killing the mites causing Scab, the dipping destroys other pests such as ticks and lice.

The most widespread disease among farm animals is Tuberculosis. This differs from many other diseases because an animal may be suffering from a mild attack and yet display none of the symptoms of the disease. It is a most serious disease, because it

can be transmitted to human beings, particularly by the consumption of infected milk. There is no known cure for tuberculosis, though the disease is more likely to develop in animals kept indoors than in those who spend most of their lives in the open air. The best hope of eradicating the disease from the stock of this country is the segregation and eventual slaughter of all infected animals. The presence of the disease in an animal can be detected by a veterinary surgeon who carries out a special test on the animal with a substance known as tuberculin. The building up of a herd of dairy cattle free from tuberculosis is a matter of long term policy. For milk production only stock free from tuberculosis should be used for breeding, and all the stock should be regularly tested, and any animals that react should be removed from the herd. This may be an expensive undertaking, and seems to call for energetic action on the part of the Government, supported to the full by the efforts of individual farmers.

Animal Losses from Livestock Diseases

It is not possible to give an accurate figure for the value of the losses incurred every year by the presence of disease among farm livestock. One estimate assesses them at 10 per cent of the value of the output of the meat, poultry, and dairy production in England and Wales. The livestock output for 1937-8, as given on page 8, amounted to £154,600,000, and the estimated loss, based on this estimate, would have been about £15,000,000. Thus the importance of eradicating disease among farm animals cannot be too strongly emphasized even on financial grounds, apart from the vital necessity of improving the standards of livestock products for human consumption. Moreover, until disease has been eradicated, the improvement of the dairy herds by selection is impossible, because the high losses among dairy cattle due to disease make it necessary to keep practically all female calves, without selection, for the replacement of losses.

Of recent years considerable attention has been given to the problem of livestock diseases. The Government has spent large sums of money on research and has organized, under the Ministry of Agriculture, a veterinary service to assist in the control of disease. The National Veterinary Medical Association has started a scheme that provides for the regular inspection, every six months, of the dairy herd of any farmer who wishes to join the scheme. Cases of mastitis, contagious abortion, Johne's disease, and sterility can be diagnosed, so that the farmer may dispose of affected animals and maintain the health of his herd. A similar scheme is under consideration to combat the problem of disease among poultry.

One incentive to the keeping of healthy animals is the payment of higher prices for the milk from herds free from tuberculosis. There are two recognized Grades of milk. Attested Milk comes from herds in which no cows show a reaction to the tuberculin test, which is carried out every six months. For Accredited Milk, the herds are inspected every three months, and cows showing clinical signs of tuberculosis must be sold.

The public are protected against some of the effects of animal diseases by the employment of fully qualified meat inspectors whose duty it is to prevent the sale of unwholesome or diseased meat. There has also been set up a National Milk Testing and Advisory Scheme, which aims at controlling the quality of milk sold, and provides advice and assistance to farmers where the quality of the milk supply is not of the required standard.

PART IV

FARMING AS A BUSINESS

CHAPTER I

ECONOMIC FEATURES OF FARMING

THE main objects of farming are the production of food and its sale at a price that brings a profit to the farmer. Farming must, therefore, be regarded as a business in which men engage with the expectation of making a living, in the same way as other men become manufacturers to produce articles for sale to the public.

Farming as a business has the one very important advantage over most other industries, because it produces food, which is one of the essential needs of man, and without some form of farming no other industry could survive. In the different countries of the world, there are great variations in the proportion of the total population employed in farming, and countries like the British Isles, which have developed to the greatest extent industrially, have the smallest percentage of their people engaged in farming. The farming population of the British Isles represents approximately 7 per cent of the total, and consequently the country has relied to a considerable extent upon imports to meet its needs for food.

USE OF LAND, LABOUR, AND CAPITAL

Farming as a business requires a combination of land, capital, and labour, known as the factors of production, and they must be utilized by the farmer in such a way as to build up a profitable undertaking. By comparison with a manufacturing industry, farming makes greater use of land ; and whilst a factory needs an area of land on which the buildings can be placed, a farmer uses the surface of the land as the medium in which to grow his crops. The use of land in this way reflects one of the most important differences between farming and industry, since farming must work in partnership with nature, and is concerned with living plants and animals.

This partnership with nature is perhaps the most important of the economic features of farming, and exercises a profound effect upon every activity of the farmer.

The effects of working with nature are many and varied. The most obvious influence of natural conditions is concerned with the seasons of the year and the weather associated with them. The farmer is subject to the control of nature in the seasons at which

he sows his crops and reaps his harvests. But weather is an unknown factor, and may seriously interfere with the work of the farmer at the season when it should be carried out. Autumn and spring are the two recognized seasons when sowing is done and the farmer expects sufficient rain to encourage germination and growth, though too much rain at these seasons delays sowing. The harvesting of cereals is a summer operation, when dry and fine weather may be expected. All too frequently, weather conditions are the reverse of the expected, leading to spring droughts and wet summers, which upset the farmer's programme. The bad effects of weather conditions on one crop are in some cases mitigated by advantages to other crops. A period of wet weather at harvest may depress the yield of a cereal crop and add to the cost of harvesting, but rain in August, if not excessive, encourages the growth of fodder and root crops, thus lessening the cost of feeding stock in the winter. In general, the British Isles are not subject to violent extremes in the matter of weather, and bad weather in this country is more of a hindrance than a major disaster.

Another result of the partnership with nature is the risk of attacks of pests and diseases on both crops and stock. These attacks may be intensified because of weather conditions. The farmer of to-day is less exposed to the risks of damage by disease because of the controls that have been developed by the scientist. The combined effect of the risks imposed by weather conditions and by attacks of disease is to make it almost impossible for a farmer to make an accurate forecast of his total production. In this respect, the farmer is at a great disadvantage by comparison with the industrialist, who organizes the work of his factory to produce a known quantity of goods, and plans for their disposal. In planning ahead, a farmer is unable to forecast accurately what quantity of wheat or potatoes he will produce, but is restricted to deciding what acreage of land he will devote to these crops. The weather may be to his advantage so that he gets an unexpectedly high yield ; or conversely, he may end the season with far less produce than he anticipated because of unfavourable conditions. Perhaps the most serious effect of unfavourable weather is at harvest time, because by then the farmer has incurred most of the expenditure on the crop. To grow a crop of potatoes will have cost about £30 an acre by the time they are ready for harvesting, and a farmer with 20 acres of potatoes has spent about £600 on the crop. With an unfavourable harvesting season, he runs a risk of a serious loss of produce from the crop on which he has spent so much time and money.

One effect of the partnership with nature is the time taken to produce a crop, or any form of livestock, in a condition suitable

for sale. The period between starting the production of a commodity and its final disposal is known as the economic lag. Under the conditions prevailing in the British Isles, practically no farm crop can grow and ripen in less than five months. When a cereal is sown in the autumn, there is an interval of ten months between sowing and harvesting. A further time-lag may occur between the harvesting of a crop and its sale. Wheat may be sown one autumn, harvested the following summer, kept on the farm in a stack during the winter, and threshed and sold in the spring. In such a case, there is an interval of a year and a half between the sowing of the crop and its disposal. There are also time-lags with root crops such as potatoes and sugar beet. The economic effect of this long period of production is a slow turnover of capital in farming. With some forms of stock-raising, the period of capital turnover may be as long as three years. Other forms of agricultural production, however, have a comparatively rapid capital turnover. The fattening of pigs for pork takes only three or four months, and six or seven months are needed for the production of bacon. Poultry hatched in the spring usually begin to lay in the autumn and bring a fairly quick return of capital. The most rapid capital turnover comes from milk production, though there is a considerable lag before a heifer has its first calf and begins to produce milk. The present organization of milk marketing in this country provides that money for the sale of milk is sent to the farmer every month. In this way, money spent on food and labour in the production of milk returns to the farm within a very short period.

In general, the profitability of a business is related to the rate of capital turnover, and a rapid turnover should result in higher profits. The same is true of farming, and any increase in the output of a farm that results from adopting more rapid forms of production often leads to bigger profits. One aspect of the slow rate of capital turnover in farming is the possibility of changes in price between the sowing of the crop and the time when it is harvested and ready for sale. This occurred in an exaggerated form on the outbreak of war in September 1939. The wheat offered for sale in the winter of 1939-40 was sold at war-time prices, but the costs in its production had been incurred in 1938-39 under pre-war conditions of costs and wages. The effect of the time-lag was to give the wheat-grower an unexpected profit due to the rise in prices during the period of production. If there is a fall in prices during the time the wheat is growing, the farmer has to face a reduction in his receipts because he cannot sell a half-grown crop to avoid being affected by a falling price. Therefore, the farmer suffers when prices are falling because of the slow

rate of capital turnover, though he reaps a corresponding benefit when they are rising. One remedy often adopted by farmers in a period of falling prices is to change to a system of farming which gives a quicker capital turnover. On a farm mainly arable, the average time for the turnover of capital is fourteen months, whilst on a grassland farm the period is reduced to seven months. This explains why in times of depression there is a tendency for farmers to turn their arable land into grassland. The reason for the more rapid capital turnover on a grassland farm is the inclusion of stock products such as milk, pigs, and poultry.

The seasonal nature of production in farming has an important effect upon the working of a farm. In many factories, it is possible to plan for regular production throughout the year, and to provide for the steady employment of labour and the adjustment of the expenses of manufacture to the receipts from sales. In farming, the work of crop production is governed by the season, and during a year there are certain rush periods, such as sowing-time and harvesting, with intervening periods of lesser activity, and an almost 'dead' period in the winter. With many forms of stock production, there are similar peak periods of activity, but not to the same extent as with crops. The uneven requirements of the farmer for labour add considerably to the problem of labour organization. During the summer, the farmer is often short of labour for the work to be done on his crops, but in winter one of his problems is to find work for his men. As an industry, farming is noted for its employment of a relatively high percentage of casual labour during the summer, and the problem of the casual labourer is to find employment in winter. To some extent, a more even distribution of labour on an arable farm is obtained by the keeping of livestock in winter, by spreading the work of threshing, by the marketing of potatoes through the winter, and by using labour for hedging, ditching, and draining. By contrast with an arable farm, work on a dairy farm is more regular and continuous throughout the year, and the biggest demand for labour is in winter, when food has to be given to the animals in yards or sheds, and when the animals need straw for litter.

The uneven character of crop production leads to difficulties in the marketing of farm produce. Food crops are ready for harvesting at certain definite times of the year, but the consumers need a regular supply of food throughout the year, and provision has to be made for the storage of certain farm products. Wheat and potatoes are often stored on the farm, the wheat in stacks and potatoes in clamps. Some products, notably fruit and vegetables, are seasonal in production and cannot be stored for any length of time in a natural condition. One method of making the distribution

of these products more even is the preservation of fruit as jam, and the canning of fruit and vegetables. Developments in cold storage are taking place, and certain kinds of fruit and vegetables can be stored and marketed in a fresh condition over a longer period of time. Recent advances in the process of dehydration have introduced another method of preservation that may lead to more regular marketing.

Another effect of the seasonal nature of farm production is the difficulty of the farmer in adjusting his income to his expenditure. This is best illustrated by taking an extreme case and assuming that a farmer is dependent upon one product only. In the case of wheat, the crop is harvested in the summer and there is produce for sale only in the months immediately following harvest. Practically all the income is received in the months from September to December. Before the sale of one year's crop, expenditure has to be incurred on next year's crop, and after the end of December there will be nothing to sell until the next harvest. In the meantime, the farmer's expenditure has to continue, and he needs money for wages, fertilizers, and for his living expenses. By June, the receipts from the previous year's harvest are probably exhausted, being partially invested in that year's crop. It is essential that, for the remaining months before harvest, the farmer can obtain some form of credit to finance the full period of production.

Under the conditions of mixed farming that prevail in the British Isles, there is not the same maladjustment of income and expenditure, though a farmer who relies largely on crops for his income has little or nothing to sell from the spring to the next harvest. Growers of potatoes and sugar beet have to spend considerable sums of money on labour at a time of the year when there is very little income. Most forms of stock production suffer from a similar disadvantage of irregularity of income. The farmer who relies on winter beef production receives most of his income in the spring, whilst the summer fattening of cattle produces its main income in the autumn. The sheep farmer derives his income at irregular intervals—from the sales of wool, fat lambs, and draft ewes. Milk production does not give a great variation in income and the dairy farmer, unlike almost any other, has something to sell on every day in the year, and receives a regular monthly cash income. One important problem in the management of a farm is the adjustment of income and expenditure, the income tending to be irregular, while the expenditure is comparatively constant. The development of mixed farming overcomes this difficulty to some extent by providing a variety of produce for sale and distributing the income more evenly throughout the year.

The Law of Diminishing Returns

It has been pointed out that the profitability of farming is largely associated with the rate of capital turnover. The production of crops and stock is a natural process and there is little prospect of increasing the speed of production. The gestation periods for farm livestock are fixed and pre-determined, and similarly the length of time required for the growth and ripening of a crop. In this respect, farming is fundamentally different from manufacturing industry, in which the outstanding development during the past century has been the increase in the speed of manufacturing processes. The application and use of mechanical methods and the development of mass production have greatly increased the speed of output, and the amount of output for each worker employed. Farming can never compete with industry in this respect and must accept the limitations of the partnership with nature. Nature also imposes a limit on the physical output that can be obtained from an acre of land. This is demonstrated by the figures given on page 103 for the use of nitrogenous manures, which show that the expenditure of capital on 2 cwt. of sulphate of ammonia gave a profitable return, but a further increase in the amount of fertilizer did not give an equivalent rise in production. The effect of this diminishing yield is to increase the cost of each unit of wheat produced, but in industry it is possible in many cases to reduce the cost of each unit of production by achieving a greater output. A factory producing a given number of pairs of boots every week can, by doubling the number of machines in the factory, produce twice the quantity of boots, and as overhead expenses do not increase at the same rate, the cost of each pair of boots is reduced.

This factor governing farm production is known as the Law of Diminishing Returns, and it has a far-reaching effect on farming. The Law says that additional intensity of farm production does not, after reaching a certain level, lead to a corresponding increase in output. The example given refers only to the use of fertilizers, but the law is equally true for other operations. In the growing of a root crop, at least two hoeings are needed, one to kill the weeds when the plants are in their early stages of growth, and a second at a later stage. If these hoeings were not done, the farmer would harvest a poor crop, and the work of hoeing is well justified by the additional yield. If the number of hoeings are increased to four or six, the farmer does not get the same extra yield for the additional hoeings. The Law also applies to the feeding of stock, and an increase in the ration of an animal does not after a certain point give a corresponding increase in milk production or live weight gain. It follows that there is a limit to the intensity of

farming, and care must be taken to ensure that the intensity of production has not passed the point where it gives no return for the effort expended.

The most important effect of the Law of Diminishing Returns is to limit the intensity of farming and the quantity of produce that can be obtained from an acre of land. The Law is also concerned with the relationship between the costs of production and the selling-price of produce. It may happen that the price of fertilizers rises at the same time as the selling-price of a crop falls. In

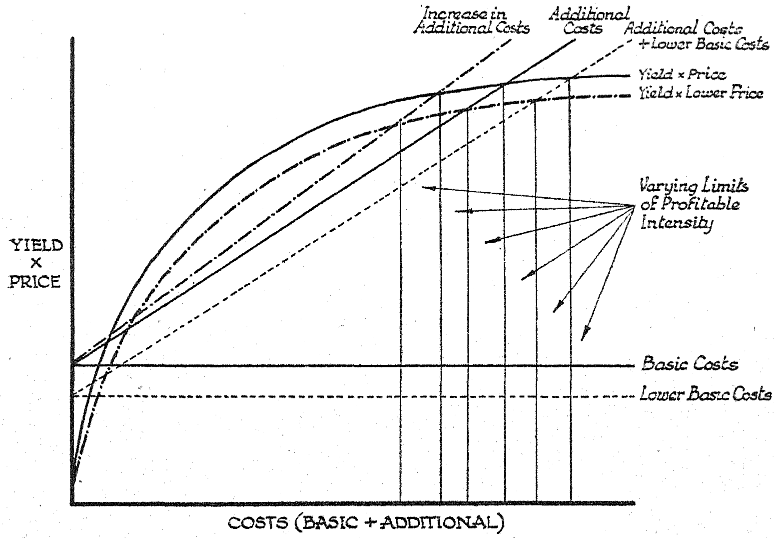


FIG. 23. THE LAW OF DIMINISHING RETURNS

these circumstances, a farmer may have to reduce the intensity of his farming because the changed relationship of cost to price may have resulted in his existing system of farming going beyond the limit of profitable intensity. The inter-play of costs and prices is illustrated by the diagram given in Fig. 23. The curved line represents the diminishing yield of a crop as the intensity of farming increases, and the additional costs, which increase at a steady rate, are represented by a straight line. Where the straight line cuts the curve is the point of the greatest economic intensity of farming, and the area between the curve and the straight line can be assumed to represent the profit from an acre. It will be seen that a rise in costs brings the straight line nearer to the curve, thus giving a lower profit ; and a drop in the curve, representing a fall in price, also reduces the profit. In either case, the change in

costs or prices results in the limit of profitable intensity being reached at an earlier stage than before the change, and the farmer should reduce his intensity of farming accordingly.

The diagram also illustrates the effect of a reduction in basic costs on profitability. The substitution of tractors for horses, or the introduction of machines to replace hand labour, would reduce the basic costs. This would be shown in the diagram by lowering the line for basic costs, which would enlarge the area representing profits. It is by cheapening the cost of production that farmers have been able to postpone the effects of the Law of Diminishing Returns.

Demand for Farm Products

The profit in farming comes eventually from the sale of produce, and, by comparison with many industrial products, the sale of farm produce has a number of unusual characteristics. The most important demand for the farmer's crops and stock is for consumption as food ; but while the demand for food is constant and regular, it is not capable of indefinite expansion in respect of quantity. Recent investigations have proved the existence of widespread malnutrition, mainly in the lower income groups, and there is a big potential market for farm products to bring the diet of many people to a reasonable standard of nutrition. This will affect the demand for products such as meat and vegetables rather than for bread and potatoes, the demand for which would never completely disappear. But a lowering of the price of bread and potatoes would not lead to the same increase in consumption as cheaper meat and vegetables. In the same way, an improvement in industrial prosperity and the payment of higher wages is more likely to increase the demand for foods of higher quality. In times of depression in industry, the demand for food does not disappear but tends to change back to the cheaper articles of food.

It can be seen that to some extent the prosperity of farming is linked with the prosperity of industry, and that an increase in purchasing power may lead to a greater demand for higher quality food. There is a limit to the extent of this change, and a further rise in purchasing power would not lead to the buying of more food, but of such articles as clothes or furniture. If there is a reduction in the price of articles of this nature, the demand for them probably increases whilst the farmer gets little or no increased demand when prices are lower. Some farm products are not used as food, but as the raw materials of industry, and the demand for products of this character is not limited in the same way. Wool for the manufacture of cloth, and hides for leather,

and flax for the making of linen, are examples of British farm products for which the demand is capable of expansion, whilst cotton and rubber are examples produced by farmers of other countries.

Processing

One problem in the marketing of certain farm products is their perishability, and they must be marketed quickly or they lose their quality. Methods of preservation to ensure a longer period of marketing have already been mentioned. Another difficulty in marketing is that many farm products are not produced in the form in which they are bought by the consumer. Wheat is sold by the farmer, but has to be ground into flour and made into bread before it is sold, and living animals must be slaughtered and dressed or processed before sale as joints of meat or sides of bacon. These services have to be performed in the course of marketing, and the farmer is necessarily dependent upon the millers, bakers, and butchers who are the intermediate agencies in the marketing of his produce.

Prices

The most important aspect of the marketing of farm produce is the price received by the farmer. In this respect, the farmer has been at a great disadvantage by comparison with manufacturers, and for many years he has grown and marketed his produce without knowing what price he would receive. The manufacturer knows the cost of raw materials and labour, and offers his goods to the buyer at a price that covers these costs and allows a definite margin of profit. The price of farm products is determined by the state of the market, and in particular, the amount of produce being offered for sale and the demand for it. It has been pointed out that the demand has a tendency to be constant, whilst natural conditions lead to considerable variations in the supply of produce. The expected result is a fluctuation in price from year to year, and, in some cases, from day to day. This lack of knowledge of selling-price is one of the most serious economic handicaps to the farmer, because one important factor in his business organization is beyond his control.

During the last fifteen years, there have been a number of developments aimed at removing some of the effects of this handicap, and providing the farmer with information on the price he will receive for his produce. In the case of milk, the Milk Marketing Board has stabilized the receipts of the dairy farmer by fixing the wholesale and retail prices of milk. The price of wheat before the war was standardized under the Wheat Act at 45s. a quarter by the payment of an additional sum for every quarter of wheat

sold. With other commodities, the principle of a contract between the producer and the consumer was being developed. The grower of beet sugar knows in advance what price he will receive, and a similar contract method was introduced for bacon pigs, though it did not operate with great success. The experience of the war, with a system of fixed prices for all farm products, has proved the advantages to the farmer of knowing his prices in advance, and some form of price-fixing machinery may become a permanent feature of agricultural organization in the future. This would remove one of the weaknesses in the economic planning of farming.

Maintenance of Soil Fertility

The organization of farming as a business differs in a number of ways from the organization of a manufacturing business. The farmer is not only producing living crops and animals, but he is dealing with another living medium, the soil. In the planning of his business organization, the farmer has to pay attention to the question of the maintenance of fertility, and, if this is not duly safeguarded, the profits from the farm will disappear in the course of time. When a factory machine is worn out, it is replaced, but once the fertility of the soil has been exhausted, nothing but a long period of rest and recuperation will restore it. The necessity of planning for the maintenance of fertility makes it comparatively rare to find a farmer relying on one product as the source of his income. In industry, there are certain advantages to be gained from specialization and concentration on one product ; but in farming, undue specialization probably leads to loss of fertility. Some degree of specialization is justified in the interests of efficiency, but the main enterprise on a farm often implies some complementary though subsidiary form of production which provides an additional source of income. A farmer concentrating on crop production may introduce livestock for the consumption of by-products and the making of farmyard manure ; and though the livestock are kept primarily for the benefit of the crops, they provide the farmer with another sale product. A farmer who relies for his income on the fattening of beef cattle on grass during the summer may introduce a number of sheep to improve the grazing of his pastures.

Farming is concerned with a number of joint products, The production of wool is necessarily combined with the sale of mutton, and it depends upon the local conditions whether the sheep are kept for their mutton with wool as a by-product or whether the main source of income is from wool, when mutton becomes the subsidiary product. Cereals cannot be produced without straw, sugar beet tops are left on the farm, and a crop of potatoes has

some proportion of small tubers, and in all these cases the full economic return cannot be obtained from the crop unless some provision is made for the proper utilization of the by-products.

Management and Costings

In industry it is possible to calculate and analyse with considerable accuracy the costs of production, and the information derived from costings has been used to ensure economic management; but when this method is applied to farming, it has been found to be of comparatively limited value. In the organization of a farm the different enterprises are interlocked and dependent upon each other, and it is nearly impossible to calculate accurate money costs for the separate departments. The crop enterprises are dependent upon stock for farmyard manure, and, in their turn, the stock are fed from the crops produced; the allocation of the costs between the two enterprises can never be other than purely arbitrary.

The farmer is the manager of his farming business, and in this respect he is likely to meet certain difficulties that do not arise in industry. Farming is concerned only with the surface of the soil, and if the size of a farm is increased by occupying a larger area of land, the outward expansion adds disproportionately to the problem of supervision and management. An extension of a factory can be made by adding another story to an existing building, or by erecting a new building close at hand, and such extensions do not cause the same difficulties in management. The problem of adequate supervision of farms is one reason why they are usually run as small business units.

It is important that farmers fully recognize the economic features of the organization of farming, and the extent to which it differs from industry. The special problems that confront the farmer are not necessarily disadvantages, particularly if he is aware of them and plans his farming to minimize their effect. Farming possesses the supreme advantage of producing to meet an essential need; and whilst the demand for a manufactured article may decline and even vanish, the demand for food can never disappear. The farmer should regard this as the most important aspect of his business, and build up an organization designed to overcome, as far as possible, the economic disadvantages inherent in farming, and produce food for his customers at a price they can afford to pay.

CHAPTER 2

THE CHOICE OF A FARMING SYSTEM

ALTHOUGH the system of farming to be adopted is to a large extent predetermined by soil and climatic conditions, there is considerable freedom of choice to an individual farmer as to the system he can follow. Bearing in mind the limitations imposed by soil and climate, every farmer should develop a farming policy to make the best use of the land, labour, and capital available. A farmer should first decide on the main forms of production he will adopt, and whether his main source of income is to be from crops or stock. He should then consider how subsidiary enterprises can be adapted to the major forms of production. In the choice of the main enterprises, the farmer should take into account the initial capital outlay, the requirements for labour and how they are distributed throughout the year, the regularity of income and the rate of capital turnover. He will be influenced in his choice by the presence of special markets, and should make certain that he can develop an economic unit of production. The subsidiary enterprises should be planned so that in crop production the best use is made of by-products, and in livestock production the farm will contribute most effectively to the food requirements of the animals. A final consideration in the selection of a farming policy is to ensure that it will result in the maintenance of soil fertility. These considerations can best be discussed in relation to the more important types of production. These can be broadly classified as crop enterprises and livestock enterprises.

CROP ENTERPRISES

The two main types of cash crops are cereals and root-crops, including potatoes, sugar beet, and in some cases certain vegetables. These forms of production have important differences, which should be taken into account in deciding the most suitable for a particular farm, providing that the soil and climate are suitable.

Cereal growing is not an intensive form of production and does not produce a high cash return from an acre, so that a large acreage is necessary to provide a reasonable gross income. The capital needed for cereal production is comparatively high because of the implements and machinery required. These include ploughs and other implements of cultivation, seed drills, and specialized harvesting machinery, and, to make the most economic use of this equipment, a large acreage of cereals must be grown. Full advantage can be taken of mechanization, almost every operation in

cereal growing can be done mechanically, and this helps to some extent to mitigate the uneven labour requirements of cereal crops. The capital turnover is slow, and the income is not evenly distributed throughout the year. The products from cereal crops are in most cases readily saleable, and, if market prices are temporarily low, the produce can be stored for a considerable period on the farm in the hope of an improved price. In extreme cases of low prices, the produce can be marketed indirectly by using it for stock feeding. As a crop, cereals are exhaustive of fertility, and the maintenance of fertility is connected in the main with the use of the straw ; and unless some form of livestock production is combined with cereal growing, the disposal of straw is a difficult problem. Cereal growing as a main form of production should only be adopted on a large scale so as to make the greatest use of mechanical assistance, and special attention should be given to the problem of soil fertility.

The growing of potatoes is, by comparison with a cereal crop, a more intensive type of production, and the cost of growing an acre of potatoes is about three times as great as the cost of an acre of cereals. The intensive nature of this crop means that a smaller acreage is needed to give the same gross income, and to justify the purchase of special equipment. Apart from the implements of cultivation, the grower of potatoes needs a ridging plough, and a special plough or potato spinner to lift the crop. One important characteristic of the potato crop is the heavy cash outlay required for the purchase of seed and fertilizers. It is a crop with heavy labour requirements at almost every stage of growing, beginning with the carting and spreading of farmyard manure, followed by the planting of the tubers, the intercultivation of the crop during its early growing period, and ending with the lifting, clamping and marketing of the crop. The peak periods in labour requirements are at the times of planting and lifting, and potato growing on a considerable scale should not be adopted unless adequate supplies of casual labour are available at these peak periods. Potato growing offers employment for regular workers for a considerable part of the year, especially when the crop is marketed regularly throughout the winter. This long period of marketing implies that the income from potatoes is spread over half of the year, but the income does not coincide with the periods of high expenditure. The yield of potatoes is likely to be more variable from year to year than with cereals, due to the effects of climatic conditions and possible attacks of disease. Potatoes are bulky in relation to their value and should be grown as near as possible to markets to avoid high costs of transport.

Sugar beet growing is another intensive form of production, but

differs in certain respects from potato growing. It requires little in the way of specialized equipment, and though the cost of growing an acre of sugar beet is about equal to that of potatoes, there is not the same high outlay for seeds, but a higher expenditure on labour. The peak periods for labour are for singling, hoeing and lifting, and, as with potatoes, casual labour will probably be needed. The harvesting of the crop is spread over a longer period than that of potatoes, but the harvesting may last until December, which is too late for sugar beet to be followed by an autumn sown crop. The price of sugar beet is fixed by a contract with the factory, and the growers' receipts depend on the total yield of the crop and on its percentage of sugar. It is possible to arrange with the factory for payments to be made on account during the growing season so that money is obtained to meet the heavy expenditure for wages. The sugar beet crop has two valuable by-products in the form of tops and sugar beet pulp, both of which are used for the feeding of stock. The costs of transport of sugar beet to the factory are high, and it may be uneconomic to grow at the crop a great distance from a sugar beet factory.

Of recent years, many arable farmers have included an acreage of a vegetable crop as a part of the root crop in the rotation. The growing of vegetables calls for specialized knowledge, and entails high labour costs, especially for planting and harvesting. The marketing of vegetable crops is not so orderly as for potatoes and sugar beet ; the crops are more perishable, and there is a danger of a glut on the market to cause a heavy loss of receipts. If the crop is marketed to good advantage, the cash receipts are high. Some vegetable crops occupy the land for a long time and this may interfere with the preparation of the land for the next crop. Vegetable crops are often grown to supply a special market such as a factory canteen, a public institution, or a hotel near the farm.

Livestock Enterprises

Dairying, or the production of milk for sale, is the most important of the livestock enterprises, because it is concerned with a product for sale that is not in competition with imported produce. As a farm enterprise it involves a high capital outlay, in respect of both animals and the special dairy equipment that is needed. It is essential that the buildings are suitable, or can be adapted for the production of milk, and that they conform with the legal requirements for the particular grade of milk to be produced. Dairy cattle require a considerable amount of labour regularly throughout the year, and need attention every day. They are exacting in the matter of food requirements, and expenditure on feeding-stuffs represents the greatest item of cost in milk production. The

milk can be marketed wholesale, or retailed by the producer, and whichever method is adopted results in a regular source of income to meet the constant expenditure involved. Milk is a perishable product and there may be a surplus of milk to be disposed of at certain times of the year. If there is no suitable market for the surplus milk, it can be used for feeding to pigs or calves. The price of milk is higher during the winter months, and it is often more profitable to produce an even quantity in summer and winter than to have surplus milk for disposal in summer. The producer of milk is always subject to the risks of disease or sterility among his animals, and serious outbreaks of disease or frequent sterility may prove costly. A dairy enterprise tends to monopolize the activities on a farm, and a farmer should not take up dairying unless he has considerable personal interest in the undertaking or has a herd of cows large enough to employ a competent cowman.

The production of beef may, in certain circumstances, be adopted as the major livestock enterprise. Farms with grassland of sufficiently good quality may follow a practice of summer fattening, the store cattle being purchased in the spring and the finished animals sold as beef by the end of the summer or early autumn. This involves a heavy cash outlay in the spring and the bulk of the income is received six months later. The profits from summer beef production depend almost entirely upon the relative prices of store cattle in the spring and of beef cattle later in the season. There is not a heavy demand for labour and little money has to be spent on feeding stuffs. Beef production may also be carried on in yards during the winter months, the store cattle being bought in the autumn. In some cases, this may be a major livestock enterprise adopted for the disposal of root and cereal crops grown on the farm; whilst in others, it uses home grown foods coming as by-products from crop production and turns straw into farmyard manure. In either case, it represents a slow capital turnover, and as a major enterprise it does not give a regular source of income.

Pigs, as a livestock enterprise, do not demand a high capital outlay. They breed rapidly and the young animals mature and are ready for sale in a comparatively short time. In this way, they represent a quick capital turnover. They consume waste products of various kinds, such as tail corn, small potatoes, skim milk and whey. The capital outlay on buildings is not so high as for dairy cattle, nor is any special equipment required except, in some cases, a steam boiler for the cooking of food. The producer of pigs often has alternative markets as pork or bacon, though a different type of pig is required for high quality produce of either kind. There are some risks of disease among pigs, and pig keeping

may become a speculative enterprise if there is too much reliance on purchased foods. A rise in feeding costs may occur with no corresponding rise in the price of the pig when marketed. Pigs may be kept on a large or small scale, and may be of great value to a man just starting farming because of the quick money returns they bring.

Sheep farming is of three main types. Mountain sheep are a major livestock enterprise, the adoption of which is entirely determined by natural conditions. Save in unusual circumstances, nothing is required in the way of housing, and the initial capital outlay is not great. The labour requirements are low, but the income, though it comes from both wool and mutton, is unevenly distributed, and the capital turnover is slow. The main problems connected with mountain shepherding are the finding of suitable winter keep for the animals, the possible risk of disease, and a spell of bad weather, particularly at lambing time. Grassland sheep do not often rank as a major enterprise, but are a useful supplement to the grazing of cattle. Their labour requirements are low, and no housing is needed. They provide an irregular source of income, but do not involve a heavy expenditure for food, and they require little special feeding. Arable land sheep have declined in importance to such an extent that they are rarely found as a main livestock enterprise, but are a valuable supplement to arable farming on light land and consume crop residues of various kinds. By comparison with other kinds of sheep, they require a considerable amount of labour when folded on arable crops. A breeding flock of arable sheep requires careful thought and planning to ensure a regular supply of feeding crops throughout the year. As with mountain and grassland sheep, the income from arable sheep comes at long intervals and the capital turnover is slow.

Poultry keeping is not often a major enterprise on a general farm, but a number of poultry are often kept to utilize certain crop residues. The capital outlay is not high, and quick cash returns are obtained, and a poultry unit can be of great economic value to a general farm. Ideally, the unit should be large enough to employ the services of a skilled poultryman, but this is not possible except on a fairly large farm. Poultry keeping is also practised as a specialized undertaking ; and provided there is no great disparity in the price of food and the price of eggs, it can make an economic business.

Major and Subsidiary Enterprises

It will be appreciated that the building up of a farm's organization to combine the right crop and stock enterprises is a matter that calls for considerable care and thought. Where crop produc-

tion is to be the main enterprise, the first necessity is the designing of a suitable rotation that gives the best output of the cash crop in question, and at the same time ensures the maintenance of fertility and the economic distribution of labour, while providing any additional food needed for subsidiary livestock enterprises. The form of livestock to be used must then be decided, and this depends on the type of by-products available, on the type of land, and the provision of yards and housing.

Similarly, planning is necessary before adopting dairying as the major livestock enterprise. The farmer should decide whether to rely largely on home-grown or on purchased foods, and should make estimates of the food requirements of his herd. From this, he can decide how much of his land should be used for hay, the acreage of root crops he should grow, and the proportion of the concentrates that can be conveniently and economically grown on the farm. The farmer must decide whether he intends to rear the female calves as replacements for his herd, or whether to sell all calves at birth and to buy down-calving heifers or cows as required.

As a general rule, a farm should not have too many enterprises, and the beginner at farming would do well at first to confine his attention to one or two major enterprises, and to add others later if necessary. The different branches of farming all require special skill and knowledge, and inexperienced farmers may lack the necessary technical knowledge to follow more than a limited number of enterprises. The economic size of the enterprise unit is of great importance. It is better to have one or two good units than a greater number of enterprises all of which are small and uneconomic.

The object in the choice of a farming system should be to secure a high output for the expenditure on labour with regular employment to the workers, a rapid turnover of capital, and reasonable regularity of income adjusted to meet the expenditure. The planning of a farm involves economic rather than technical efficiency. Economic efficiency implies the best combination of crops and stock to meet the circumstances of the particular farm, whilst technical efficiency includes the proper care of stock and the skilful growing of crops. In general, technical efficiency amongst farmers is higher than economic efficiency. Many farmers are capable of growing a good crop of wheat or feeding a dairy cow to give a good yield of milk, but are unable to decide what proportion of their farm is most economically devoted to growing wheat, or what is the most economic size of dairy herd to be kept. Only if a farm is organized on a sound economic plan can full benefit be derived from technical efficiency.

CHAPTER 3

TAKING A FARM

THE first essential in becoming a farmer is to take a farm. The choice of a farm is a matter on which the prospective farmer may have certain definite ideas, and he may be seeking a farm on which he can carry on a particular system of farming, or he may defer the choice of the system until he has found a farm which he considers suitable from other points of view.

RENTING OR BUYING

The prospective farmer may wish to buy a farm, or to rent one from an owner of land. The question of the desirability of owning a farm is largely answered by the amount of capital available. The freehold value of a farm is approximately twice as much as the capital needed for its working. This means that buying a farm takes about two-thirds of the capital available. The return on capital invested in land is not high, and, over a period of years, probably does not exceed 4 per cent. With the same amount of capital, a farm three times as large can be rented, and the return on the capital, while it may fluctuate from year to year, should certainly be higher when used as tenant's capital. At the present time, the relationships between landlord and tenant are governed by legislation which gives the tenant important safeguards. In normal circumstances, especially for a beginner at farming, renting a farm is preferable to buying, and enables the farmer to change to a bigger or a different farm with comparative ease.

SIZE OF FARM

The size of the farm to be taken is an important consideration ; in general terms, it should be large enough to make full use of the capital available, but not too big, so that the whole undertaking is under capitalized. The size of a farm has an effect on the system of farming to be adopted, and the smaller farms tend to follow more intensive forms of production, provided the soil is of a type that favours intensive cultivation. The size of farm depends upon the amount of capital to be invested and whether the farmer intends to devote his time entirely to management, or to take some part in manual work as well as managing other paid labour, or to have no paid workers and rely on the labour of himself and his family.

A choice may have to be made between two farms, one with a high and the other with a low rental value. Generally speaking, if the necessary capital is available, it pays to take the better farm

with the higher rent, as this is a measure of its potential productivity. There may be exceptions to this when the rent for a particular farm is high, not for reasons of soil fertility, but because of a special amenity in the form of buildings, or nearness to a town.

Taking a farm as a tenant implies the signing of a legal document under which the tenant is granted the lease of a farm for a specified number of years, or holds the farm under a yearly agreement. Before this document is signed, the tenant should study the conditions under which he is taking the farm, and should make enquiries as to the local customs in respect of tenant right valuation. The basis on which the ingoing valuation is paid for by a new tenant varies considerably from one district to another, and may be such as to affect the amount of working capital left to the tenant.

Capital Requirements

It is almost impossible to give any definite figures for the amount of tenant's capital required for a farm. The amount varies according to the type of farming to be followed, and it may assist a prospective tenant to indicate the various purposes for which working capital is required, so that he can make an estimate for a particular farm. Working capital is needed for three main purposes. Firstly, capital is needed for the equipment of the farm with productive livestock, implements, machinery, and working horses. Secondly, capital is required for the payment of the tenant's ingoing valuation, which represents value in the form of manurial residues and cultivations left on the farm by the previous occupier. Lastly, capital has to be spent on seeds, manures, feeding-stuffs, and labour in order that the different forms of production can be started and maintained. The farmer also needs a part of his capital for living expenses until produce is available for sale. It is always prudent for a young man beginning to farm for the first time to have a reserve of capital in case of misfortune during his first year, so that a temporary setback does not make it impossible for him to carry on. In 1939, the tenant's capital for farming was estimated to range from £10 to £18 an acre according to the type of farming. In addition to the capital belonging to the farmer himself, additional capital can be obtained in the form of bank or merchant credit, but too much reliance on borrowed money at the start of a farming venture is not to be recommended.

Selection of Farm

Having considered the amount of capital available and the type of farm required, the prospective farmer should, if possible, inspect a number of farms before making a choice. It is well nigh

impossible to find a farm that is ideal in every respect ; but when looking at a farm, there are a number of points to be borne in mind that will assist in making the final choice.

In the first place, there are certain general considerations with regard to the farm as a whole. The prospective tenant should study the situation of the farm and its accessibility to good roads, a railway station, and markets, and whether the farm is provided with a public supply of water and electricity. The farm itself should be inspected from the point of view of its aspect if it is to be used for crops, and the extent to which it is protected by trees or shelter belts if livestock are to be kept. Attention should be paid to the size, shape, and lay-out of fields, the state of the farm roads, the ease of getting to the more remote parts of the farm, and the general condition of the boundary and internal fences. As the farm is to be a home as well as a business, the condition of the farmhouse is a matter of considerable importance to the farmer and his wife, and the number and condition of the farm cottages have an important bearing on the labour supply. Nothing is more likely to attract labour of good quality to a farm than pleasant, well planned, and up-to-date farm cottages. The distance from the farm to the nearest village, from which additional labour can be obtained, and the amenities for shopping and for schooling, are other factors which should be considered.

Following these more general considerations, a careful examination of the soil of the farm is essential. It is not sufficient to look at the surface soil, but holes should be dug in a number of places to gain information as to the subsoil. Some estimate should be made of the potential fertility of the farm by making enquiries as to the normal yields of crops that might be expected, and the manuring policy followed by the previous tenant. Observations should be made as to the cleanliness of the land and the state of the ditches, and information sought as to the system of drainage and its effectiveness. The proportion of grassland to arable land should be considered, and enquiry made as to any restrictions that may be imposed on the ploughing up of permanent grass.

Finally, the buildings on the farm should be inspected, with special attention to their lay-out and the ease of working in them. The position of the buildings in relation to the lay-out of the farm should be considered, especially with regard to the more distant fields and the possible costs of bringing produce from them to the buildings, and the carting of farmyard manure to the fields. With reference to the buildings themselves, consideration should be given to their suitability for dairying, or for the keeping of other forms of stock, and the ease with which they may be adapted to a particular purpose.

The various considerations that have been put forward in the selection of a farm may be ideal and impossible to find in practice. But they form some basis on which one farm may be compared with another; and if the choice cannot rest on the greater advantages of one farm, it may be necessary to decide on the farm with the smallest number of disadvantages.

CHAPTER 4

MANAGING A FARM

IT requires a considerable range of ability to be a successful farmer. He should not only possess a practical knowledge of farm operations and a technical knowledge of crop and animal production but be able to keep simple records and accounts, to direct the efforts of his workmen, and be competent at buying and selling and sensing the trend of markets and prices. As a manager, a farmer is responsible for the policy of the farm and has to decide how the factors of production represented by the land, labour and capital at his disposal can be used to the best advantage. Management has been described as a fourth factor of production, since it is responsible for the proper combination of the other three factors. It is a function of management to decide what forms of production should be adopted, the probable amounts of produce that will be available for sale and the methods of production likely to give the best results. The principles governing the selection of a farming system have already been discussed and the management of a farm is responsible for putting a selected plan into operation.

FARM BUDGET

Having selected the systems of production to be adopted, a more detailed plan should be drawn up for the working of the farm. This is known as a farm budget and is a statement in general terms of the probable income and expenditure to be expected, given reasonable conditions. A form on which a farm budget could be drawn up is given in the Appendix. A budget implies a forecast of what may happen on the farm in the course of a year : while it will probably not be completely accurate, it acts as a guide to the farming programme. Many of the expenses on a farm can be estimated with a reasonable degree of accuracy. The rent of the farm is known in advance, wage rates are fixed, and the prices of feeding-stuffs, seeds, and fertilizers do not change rapidly. If costs rise in the course of the year, the budget can be adjusted accordingly, and if they fall it is to the farmer's advantage. The estimate of receipts may be less reliable but should be based on average yields and prices, and the estimate can be adjusted in the course of the year as necessary.

In drawing up a budget for most farms, the anticipated expenditure may be classified under a small number of headings. The main items are wages, feeding-stuffs, purchases of livestock, seed and fertilizers, repairs to implements and machinery, rent and

miscellaneous. It should not be difficult to make a forecast of expenditure under these headings, with the possible exception of miscellaneous expenses, which is an item that calls for the special attention of a farmer as a likely source of wasteful expenditure. The estimate of income would probably be less accurate ; but using conservative figures for both yields and prices, it is of great assistance in good farm management. With the crops, it is necessary to decide which of them are to be sold and which retained for the feeding of livestock. The income from livestock can be estimated from the anticipated production of milk and eggs and from the number of fat and store animals likely to be available for sale.

The greatest effect of management is in the control of the expenditure of the farm. The amount of produce for sale is largely a matter of technical efficiency and it is possible to have good yields from the crops and stock on a farm whilst the accounts show only a small margin of profit. This would happen under an extravagant system of production with insufficient attention paid to the different items of expenditure.

Organization of Labour

Special attention should be given to the organization of labour, because wages represent the largest single item of expense on most farms. It is important that money spent on wages should be used to its best advantage, and profits on a farm depend to a considerable extent on the economic use of labour. There are few other industries in which the human relationship between employer and employee is of greater importance than in farming. The number of men employed is small and the farmer often works with his men. This intimate contact makes the control of labour on a farm different from the control of large numbers of men in a factory. There is not the same degree of specialization, and most workers on a farm have to undertake a great variety of tasks, often changing their tasks two or three times in the course of a day.

The wages paid to farm workers are under the control of Wages Boards set up by the Government. The action of the Wages Boards has fixed the rate of wages, and economies in the cost of labour cannot be achieved by a reduction in wages. For this reason, the available labour should be used to its best advantage. The farmer does not control the rate of pay to his workers but he is responsible for the number of hours they spend on the different departments of the farm and in this way he can exercise considerable control over the cost of labour. The economic use of labour is best achieved by the joint action of the farmer and

his workers. Many well managed farms pay their better workers a higher wage than the minimum rates laid down by the Wages Boards. This puts a premium on efficiency, the better workers getting a higher wage. In other cases, farmers use the system of payment for piece work, which increases the speed at which the work is done and gives the good workers an opportunity of earning more than the minimum wage. When a system of piece work is used, care must be taken to ensure that the work is not badly done in order to increase the speed. Many farms have a system of bonus payments for work that demands special care and attention, especially in the case of the men responsible for the care of livestock. Bonuses are often paid for the number of calves, lambs, or pigs reared, as an encouragement to the stockman to spend extra time on the care of young animals. Some farmers pay a bonus for the production of clean milk, the basis of the payment being a low bacterial content of the milk. Bonus payments act as a great incentive to workers to take an interest in their work and to try and carry out the wishes of the employer.

One of the most important factors in the efficient use of labour on a farm is the even distribution of work throughout the year, and this is primarily a matter of the way in which the various systems of production are combined. It is important from the point of view of both the farmer and his workers. The farmer wants a labour force which is as regular as possible and he may plan special enterprises to employ his workers during the winter so that he has adequate labour for the summer and is more or less independent of casual labour. It is only to be expected that men with a prospect of regular employment do better work than men who are engaged as casual workers. Some economy in the use of labour may be achieved by the avoidance of an excessive amount of unproductive labour such as may occur when men are changing from one operation to another. Time may be wasted by the bad layout of the farm or by badly designed buildings or because insufficient thought is given to the planning of the labour operations for the day. Waste of labour occurs when men are idle at a busy season of the year through a breakdown in machinery. This can be avoided to some extent if preparations are made in advance and supplies of spare parts obtained and machinery overhauled well before it is needed. It is impossible to give in detail all the various ways in which the cost of labour can be reduced, as conditions vary from one farm to another. But there is probably no direction in which good farm management is more effectively applied than in the proper organization of labour, and every farmer should devote considerable attention to this aspect of management.

Purchase of Seeds and Fertilizers

The expenditure on seeds and fertilizers is an item of some importance on a farm relying on crop production, and the preparation of a cropping plan enables requirements to be ordered well in advance. It is usually false economy to save money by the purchase of cheap seed or inadequate supplies of fertilizers because the amount of produce for sale depends upon wise expenditure in this direction. The ordering of requirements in advance often leads to economies because supplies can be bought in bulk at cheaper rates and special discounts are often given by merchants for early delivery. Moreover, if the necessary seeds and fertilizers are available on the farm, full advantage can be taken of favourable spells of weather for sowing them and a saving of time in this way is a saving of money.

Feeding Costs

Where livestock enterprises are an important feature of the farming system, the expenditure on feeding-stuffs represents a major item of cost and may exceed the cost of labour. The price of feeding-stuffs is usually a matter beyond the control of the farmer but some economies in cost may be effected by bulk purchase and by a study of the relative prices of different feeding-stuffs. The greatest scope for the economic use of foods is on the farm, and the rations for all farm animals should be calculated to give the most economic return of meat or milk. Once a ration has been drawn up the farmer should make sure that it is being fed correctly to the animals, as frequently a little extra food is given by the man in charge of the stock. Small additions to the rations result in considerable wastage over a season. With a herd of twelve dairy cows, an extra half a pound of dairy cake to each animal would represent, in the course of the winter, nearly half a ton of cake, and at £15 a ton the wastage amounts to £7 10s., the value of about 75 gallons of milk. Wastage at this rate is the equivalent of throwing away all the milk produced by the herd for three days. Great importance should be attached to attention to detail in the feeding of livestock and the farmer should take considerable personal interest in his livestock to avoid unnecessary wastage of this kind.

Fixed and Additional Costs

The total expenditure on a farm makes up the costs of production, but it is important to distinguish between what may be called fixed costs and additional costs. In crop production, the fixed costs consist of rent, overhead expenses, and the labour needed for the preparation of a seed bed ; whilst for livestock, they include

labour and the rations fed for maintenance. The additional costs are made up of the items designed to increase the output and include seed, fertilizers for crops, and the production rations in the case of stock. In one sense, the additional costs represent the intensity of the farming system and the degree of technical efficiency. The aim of good farm management is to achieve a high rate of output in relation to the fixed costs. As an example, the fixed costs of cultivating a field are the same whether the yield of the crop is low or high, and a high yield means a lower cost of cultivation for every unit produced. Similarly, the maintenance ration of a cow giving 400 gallons of milk is practically the same as that of one giving 800 gallons. With the higher yielding cow, the cost of the maintenance ration for every gallon of milk produced is halved, or, expressed in another way, to obtain an output of 800 gallons from two low-yielding cows needs twice the quantity of food for maintenance.

Marketing

Apart from the day to day control of expenditure, farm management is concerned with the marketing of farm products to the best advantage. The way in which farm produce is put on to the market varies with the type of product. In some cases, the price is practically fixed by a system of contracts or through some form of national marketing organization and from the farmer's point of view, marketing is concerned with the amount of produce sold and the quality and condition in which it is sold. When the produce has to be sold on an open market, as happens with cereals, or livestock as meat, the farmer should keep in touch with the movement of prices and market his produce accordingly. The farmer should also watch the markets to decide on the best time for making purchases, particularly of livestock.

Capital Expenditure

Another aspect of farm management is the expenditure of capital on new equipment. Whilst it is important that a farm should be properly equipped for the form of production that has been adopted, it is uneconomic to spend capital on equipment that does not add to the total output of the farm. When deciding on the purchase of new equipment, the farmer should calculate whether the expenditure will lead to an increase in output or result in a substantial reduction in costs. When deciding whether to purchase a tractor for use on a farm, the farmer should consider the possible effect on the organization of his farm. With a tractor, he may be able to farm a greater area of land or put some of his grassland under the plough. In both cases, this should lead to an increase in output to justify the expenditure of capital. On

the other hand, he may calculate that the purchase of a tractor may enable him to sell one or two horses and possibly save the wages of one man and at the same time help him to get the work done better and more quickly. This would mean a substantial saving in cost and an increase in efficiency. Farmers often invest capital in a motor lorry in the expectation that it will save time in the delivery and fetching of produce. Often there is no reduction in the number of horses on the farm, and no increase in production of output ; and unless the saving of time is substantial and used productively, the investment is uneconomic. When considering the question of additional equipment it is advisable to investigate the possibilities of extra help from a contractor, which does not involve capital expenditure. One of the difficulties with farm equipment is that it is often used for comparatively short periods of the year and the rate of depreciation is high. Shortage of capital is a common cause of failure in farming but unwise expenditure of the capital available may lead to the same result with much less excuse or justification.

Use of Accounts

No farmer can manage his business properly without adequate records and a sound system of accounts. An American writer has described the management of a farm without records as being the same as having a clock with no hands. It is not necessary to have an elaborate system of accounts and all that is needed is a cash book in which the payments and receipts are recorded, and an opening and closing valuation of the assets on the farm from which a balance sheet is constructed. A simple form in which the accounts can be presented is given in the Appendix. Where possible, a more detailed record should be kept of the main enterprises on a farm. With a dairy herd a record should be kept of the various items of cost and these should be calculated on the basis of the number of cows in the herd and on the number of gallons of milk produced. The records should be kept in such a way as to enable costs to be worked out, not only in terms of money cost, but also on the basis of the number of man hours and the amount of starch equivalent used for each gallon of milk. If records are kept over a number of years, a farmer can see whether his efficiency is improving or not.

Many farmers are unaware of the fact that they can obtain assistance in the keeping of accounts and in the general problems of farm management from the Advisory Economist, who is one of the specialist advisory officers provided by the Ministry of Agriculture. Details of the services available can be obtained from the County Organizer. Many farmers realize that they have to

keep accounts for the purposes of Income Tax, but are not aware of the usefulness of accounts in farm management. A system of accounts will serve not only a as record of what has happened during the past year, but as a valuable guide to future efforts.

The farmer who has prepared a budget and has kept a record of the working of the year is able to compare his forecast with the actual results obtained. In time, this will lead to greater accuracy in the making of the budget. It must not be forgotten that farming is a business, and no business will run efficiently for long without a plan and without a record of results.

Changes in Policy

The final aspect of farm management to be discussed is the examination from time to time of the organization of the farm with a view to its improvement. If at the end of a year, the results are not as satisfactory as might have been expected, the organization should be examined to see whether the poor result is due to economic or technical inefficiency. When drawing up the farm budget, it is advisable to work out alternative budgets and compare the possible results. A farmer may be debating whether he should increase the acreage of cash root crops on the farm and reduce the acreage of cereals and alternative budgets should be drawn up to show the effects of the change. The farm may be able to carry three or four more breeding sows, or the size of the dairy herd may be increased without any important increases in labour. The question of substituting a tractor for horses can also be decided partly in the light of two alternative farm budgets. There is probably no system of production or management that is not capable of improvement or which may not need adjustment at some time in the light of changes in prices or costs. The only sound basis on which to make changes in the organization of a farm is reliable information about the existing system and careful budgeting to ascertain the probable effects of any changes that may be made.

CHAPTER 5

AGRICULTURE AND THE STATE

ONE of the most important factors affecting farm profits is the price obtained for produce and it is only in recent years that any steps have been taken by the Government to influence the price level of farm products. The industrial developments that have taken place during the last 150 years have left farmers in a weak bargaining position for assistance from the Government. The treatment of agriculture by the State has been in accordance with the general commercial policy of free trade or "do as you like." The farmers were left to choose their own systems of farming according to their profitability and the prices of home-grown produce were largely determined by imports. Until 1931, government control and assistance of the industry was comparatively limited. Farmers received some indirect assistance in respect of the relationships between landlords and their tenants, the derating of agricultural land and protection for the quality of feeding-stuffs and fertilizers. The two most important actions of the State towards agriculture prior to 1931 were the introduction of Wages Boards and the payment of a subsidy for the growing of sugar beet, both of which were introduced in 1924. Some legislation was introduced in an attempt to improve the marketing of agricultural produce by the use of the National Mark which was adopted in 1928 as a guarantee of quality of produce.

In 1931, there was a serious economic crisis throughout the world which resulted in important changes in the commercial policy of Great Britain. There was a complete change in the attitude of the Government towards agriculture and it may be said that since then the Government has adopted a positive policy towards the industry. One of the first actions to be taken was to place import duties on certain horticultural products to give protection to home-grown vegetables. By 1933 there were import duties on all foods coming from countries outside the British Empire. In 1932 the Government passed the Wheat Act which gave a guaranteed price for wheat and this was followed by subsidy payments on fat cattle and on barley and oats. In 1937, the Government gave a subsidy to farmers to encourage the use of lime and basic slag and in March 1939 paid a subsidy of £2 an acre for the ploughing up of permanent grassland. The result of this change of policy has been a considerable amount of legislation affecting the farmer and large sums of money were paid in subsidies to assist farming prosperity.

The action of the Government is discussed in more detail under the headings of wages, marketing subsidies and taxation.

Legislation affecting Agriculture

The wages of agricultural workers first came under official control during the war of 1914 to 1918 when a national minimum wage was fixed. In 1924, Wages Boards were re-constituted on a county basis. Every county has a Board consisting of representatives of the workers and of the farmers and a small number of independent members. The Boards meet at regular intervals and fix the rate of wages to be paid to the farm workers in the County. Once the wage rate has been fixed, it is enforced by law and the Ministry of Agriculture employs a number of inspectors to see that the official rates of wages are paid. One effect of the action of Wages Boards has been the absence of industrial disputes in farming and the method by which wages are settled is valuable because of the independence of the Board.

Another action of the State for the benefit of farm workers was the introduction of a special scheme of unemployment benefits in 1935. Before that time farm workers were outside the system of unemployment insurance for other workers. One of the problems of many farm workers is that of casual employment which means that they are often out of work during the winter months. The special scheme was introduced to meet this difficulty, though the rates of deduction under the scheme are lower than for industrial workers. The State has also endeavoured to improve the standard of rural housing. Under an Act passed in 1925, grants and loans were available for the re-conditioning of rural houses provided that no increase in rent was made to the farm worker living in the cottage.

On the subject of marketing, the most important action taken by the State was the passing of the Agricultural Marketing Act in 1931. This act laid down the procedure by which farmers could combine together to set up for themselves boards for the marketing of farm products. It is important to remember that marketing boards are not government bodies but have been set up by the farmers and are administered by a board whose members are elected by the farmers. One important feature of the procedure laid down under the Act is that, if a majority of farmers are in favour of the scheme of marketing, the minority are compelled to conform with the scheme or to stop producing the particular commodity. This compulsion is justifiable on the grounds that any improvement in price from the scheme would benefit non-members to the same extent as members.

In 1933, four marketing boards were established, the commodities controlled being milk, bacon pigs, potatoes and hops. The Milk Marketing Board was started to reorganize the marketing of milk for the whole country. Its main object was to even out the fluctuations in price between milk for liquid consumption and milk for manufacturing purposes and to reduce the variations in price between one part of the country and another. The existence of the Milk Marketing Board has given a high degree of stability to the price of milk and by 1939 had resulted in an increase in the quantity of milk produced. This was in itself an indication of the benefits conferred by the Board on milk producers.

The Pig Marketing Board set out to improve the marketing of pigs for bacon by drawing up a contract between pig producers and the bacon factories under which the price of bacon pigs was to be related to the price of feeding-stuffs. The scheme did not work as successfully as had been hoped because a rise in the retail price of bacon resulted in a lower consumption. On the outbreak of war in 1939, a scheme was about to be introduced which it was hoped would insure both a good price to the farmer and a fair price to the consumer.

The Potato Marketing Board did not fix the price of potatoes but devised a scheme to adjust the supply of potatoes reaching the market to the demand. This was done by regulations governing the size of potato which could be marketed for human consumption and controlled by changing the size of the riddle through which the potatoes would pass. If the Board considered that too many potatoes were being marketed, thus causing the price to fall, the size of the riddle would be increased to reduce the quantity of potatoes marketed until the price reached a reasonable level. In this way, potato growers were protected from a serious fall in price due to a glut of potatoes on the market. When the Board was first set up, it was considered necessary to prevent a sudden increase in the acreage of potatoes and growers were given a basic acreage and up to 1939, farmers wishing to start growing potatoes or extending their acreages had to pay a levy of £5 an acre to the Board.

The fourth of the marketing boards was set up to deal with hops and operates for the small number of hop growers in the country. The Board has complete control of the acreage and price and has created something of a monopoly in the growing and marketing of hops in the country. Schemes for the establishment of other marketing boards have been put forward but no new boards were set up. This may be due to the fact that farmers found that marketing boards exercised a considerable control over their activities

and they preferred a simpler form of assistance from the State.

One form in which assistance is given by the State is a subsidy which is a direct payment from government funds to encourage the production of a particular crop. Before 1931, the only crop on which the Government paid a subsidy was sugar beet. This crop had been grown on a small scale in Norfolk for a number of years and in 1924, the Government decided to pay a subsidy to assist in establishing sugar beet as a cash root crop in British farming. The subsidy was paid to the factories and enabled them to pay a better price to the farmer for his beet. The subsidy was to be paid for a period of ten years but at a decreasing rate and it was hoped that at the end of that time the industry would continue without further assistance. This proved to be impossible due to a fall in the world price of sugar and in 1934, an Act was passed to give a permanent subsidy to the crop. One of the conditions of the subsidy was that the area under the crop should not exceed 375,000 acres.

After 1931, one of the first of the British farm crops to receive help from the Government was wheat. Under the Wheat Act of 1932, a Wheat Commission was set up whose duty it was to calculate the average price of British wheat for the year ending each July and to pay to farmers a sum to bring the price of wheat to 10s. a cwt. or 45s. a quarter. This was known as a deficiency payment and the necessary money came from a levy on all flour milled or imported into the country. When a farmer sold his wheat, he obtained a certificate from the buyer stating the number of quarters sold and that it was fit for milling and it was against these certificates that a farmer claimed the deficiency payment. The levy on flour was in turn passed on to the bakers and was ultimately paid by the consumers of bread, though the extra price on a loaf of bread was very small. This scheme is generally known as the "wheat quota" and was of great assistance to farmers who relied on wheat as their main cash crop. In five years, it led to an increase of about half a million acres under wheat.

One of the effects of the economic crisis in 1931 was a fall in the price of beef and by 1934 the position of the home producer of beef was very serious and the Government introduced a system of subsidies as a temporary measure. In 1937, the Government set up a Livestock Commission which became responsible for the payment of the subsidy, subject to an annual limitation of £5 millions. The rate of subsidy was 5s. a cwt. for ordinary grade and 7s. 6d. a cwt. for quality grade. If the animals were imported, the subsidy was reduced to 2s. 6d. and 5s. for the two grades. The Commission was also given power to improve the marketing of fat cattle.

In 1937, the principle of subsidizing farm crops by a direct payment from Government funds was extended to oats and barley. The subsidies were only paid if the price of oats fell below 8s. a cwt. and was paid on an acreage basis for both oats and barley. When the Act was first introduced, a farmer was not allowed to receive a payment under the Wheat Act and a subsidy on oats and barley but this was subsequently amended, though a lower rate of subsidy was payable.

Also in 1937, another form of subsidy was introduced by the payment of a part of the cost of lime and basic slag. These subsidies reduced the price of lime by 50 per cent. and of basic slag by 25 per cent. Their use was a method of building up the fertility of the soil and the Government help was intended as an encouragement to farmers to use greater quantities. This policy of encouraging a better standard of farming was also evident in the subsidy introduced in the spring of 1939 of £2 an acre for the ploughing up of permanent grassland. This was a foreshadowing of the Government's action on the outbreak of war in September 1939 to increase the production of food at home.

The payment of these subsidies had the effect of increasing the income of the farmer from certain products and of lowering his costs. Another way in which costs were reduced was by relief from the payment of certain taxes, the most important of which was the de-rating of agricultural land. The local rates on agricultural land were first halved in 1896 and they were put on to a quarter basis in 1923. In 1929, agricultural land and buildings were completely de-rated and freed from the payment of local rates. The basis of assessment for local rates is the annual value of land and buildings occupied, and as a farmer must of necessity occupy a large area of rateable property for his business, he was paying proportionally more in rates than most other businesses of a similar size and turnover. Until the outbreak of war, the farmer had a valuable concession in the matter of the payment of Income Tax whereby he paid under a special Schedule which assumed that his income was equal to his rent. This was withdrawn in 1941 from farms with an annual value above £100. The reason for the pre-war concession was said to be the inability of a farmer to keep accounts.

Research and Education

In addition to the direct assistance given to the industry, the State spends public funds on providing facilities for research, advisory work, and education for the benefit of the farming community. A number of research institutes are maintained in different centres whose staffs are constantly in search of new knowledge that will ultimately benefit the farmer. Provision is made for

advice to be given to farmers of both a specialist and general character. There is now (1945) a plan under consideration for the establishment of a National Advisory Service that will enable new knowledge to be given to the farmer and will help him to solve the many problems arising in his business. Formal education is provided, partly at the expense of the State, at Universities, Agricultural Colleges, and Farm Institutes. It is the function of the Universities to train the future research, advisory, and educational officers for whom a degree is necessary. The Agricultural Colleges are associated with two-year courses leading to Diplomas suited to the needs of those who intend to farm on a large scale. The Farm Institutes are established by County Councils and are concerned with courses lasting for one year and intended to meet the needs of the future smallholder and the workers who will take responsible posts on farms.

It will be seen that by 1939 the State had assumed a high degree of responsibility towards the farmers, and the annual cost to the taxpayers of the country was considerable. There was, however, little or nothing asked of farmers in the matter of efficient farming. The future of the industry is at present unknown and it remains to be seen whether, if assistance is to be given to farmers, the State will ask in return that the industry should do all in its power to add to its efficiency and so justify the policy of financial assistance.

APPENDICES

APPENDIX I

TABLE SHOWING DISTRIBUTION OF CROPS AND STOCK COUNTY IN

(All figures calculated to

	TOTAL ACREAGE OF AGRICULTURAL LAND (including ROUGH GRAZINGS)	PERMANENT GRASS	ROUGH GRAZINGS	ARABLE LAND
	1939	1939	1939	1939
ENGLAND				
Bedfordshire	246,700	49	4	47
Berkshire	341,200	56	10	34
Buckinghamshire ..	371,900	78	4	18
Cambridgeshire ..	266,100	24	3	73
Isle of Ely	213,500	19	1	80
Chester	510,600	65	6	29
Cornwall	725,200	39	16	45
Cumberland	848,800	40	41	19
Derbyshire	504,100	72	15	13
Devon	1,488,100	47	26	27
Dorset	484,900	65	15	20
Durham	510,900	49	26	25
Essex	728,600	41	6	53
Gloucestershire	639,200	71	5	24
Hampshire	658,500	44	20	36
Isle of Wight	72,000	57	19	24
Herefordshire	465,500	69	6	25
Hertfordshire	291,900	46	5	49
Huntingdonshire ..	204,000	41	3	56
Kent	678,600	57	1	37
Lancashire	821,200	60	18	22
Leicestershire	449,100	84	1	15
Lincolnshire (Holland)	239,300	19	1	80
Lincolnshire (Kesteven)	409,900	39	1	60
Lincolnshire (Lindsey) ..	847,400	39	2	59
Middlesex	34,100	59	10	31
Norfolk	1,053,800	25	8	67
Northamptonshire ..	500,300	76	2	22
Soke of Peterborough ..	43,200	43	3	54
Northumberland ..	1,137,200	44	44	12
Nottinghamshire ..	415,900	54	3	43
Oxfordshire	396,300	63	3	34
Rutland	86,800	68	2	30
Salop	748,700	70	8	22
Somerset	879,500	75	11	14
Staffordshire	562,700	75	5	20
Suffolk, East	458,700	31	7	62
Suffolk, West	310,600	23	8	69
Surrey	196,700	64	14	22
Sussex, East	356,300	70	15	15
Sussex, West	269,200	56	15	29
Warwickshire	476,800	77	4	19
Westmorland	461,300	42	52	6
Wiltshire	735,200	59	19	22
Worcestershire	364,800	68	5	27
Yorkshire, East Riding ..	665,700	37	2	61
Yorkshire, North Riding	1,200,000	44	33	23
Yorkshire, West Riding .	1,370,100	54	25	21
TOTAL—ENGLAND ..	25,741,100	53	14	33

PER 100 ACRES OF AGRICULTURAL LAND FOR EVERY ENGLAND AND WALES

the nearest whole number.)

WHEAT	BARLEY	OATS	DAIRY CATTLE	OTHER CATTLE	SHEEP	PIGS	POULTRY
1939	1939	1939	1939	1939	1939	1939	1939
14	2	5	6	10	27	17	155
9	4	5	12	9	22	12	152
5	—	4	12	16	53	12	164
19	14	7	4	6	19	20	185
25	2	6	3	6	3	25	172
4	—	7	31	15	21	23	312
1	1	6	14	19	40	27	239
—	—	5	9	14	88	3	136
4	—	2	19	14	29	8	199
2	1	6	9	14	66	11	183
3	2	3	16	8	31	10	159
4	1	7	8	12	58	6	126
15	9	5	8	7	23	28	282
5	1	3	12	14	50	12	157
7	3	6	11	6	21	12	194
4	3	4	16	9	19	27	164
4	1	4	9	17	100	9	159
16	5	7	9	9	22	15	200
19	4	4	4	9	22	13	114
5	2	3	8	7	116	14	254
3	—	7	20	13	54	19	753
5	—	2	14	23	59	8	190
20	1	7	3	9	5	26	239
16	9	5	5	10	40	9	127
14	8	6	6	11	47	12	209
2	—	2	12	9	14	54	152
11	18	5	5	8	20	19	199
7	2	2	8	20	73	7	114
15	9	4	6	11	39	9	123
1	1	2	4	13	101	2	39
11	2	7	9	14	34	12	184
9	4	5	9	15	43	12	164
6	8	2	5	19	72	4	100
4	2	4	15	17	77	15	204
2	1	2	17	13	43	15	196
5	—	4	24	16	40	10	257
13	15	5	7	8	19	31	226
16	16	5	4	5	26	25	213
4	—	3	14	8	17	15	290
3	—	3	15	11	43	10	234
7	1	6	14	9	28	11	210
5	—	3	12	17	63	10	168
—	—	2	8	11	104	1	141
5	2	3	16	7	29	12	139
4	—	3	9	14	57	16	279
13	9	10	5	10	62	16	160
3	4	5	6	11	68	8	136
5	1	4	11	11	59	11	243
6	3	5	11	12	52	13	202

APPENDIX I *(continued)*: TABLE SHOWING DISTRIBUTION OF CROPS AND IN ENGLAND

	TOTAL ACREAGE OF AGRICULTURAL LAND (including ROUGH GRAZINGS)	PERMANENT GRASS	ROUGH GRAZINGS	ARABLE LAND
	1939	1939	1939	1939
WALES (incl. MONMOUTH)				
Anglesey	160,900	65	15	20
Brecon	488,400	28	65	7
Cardigan	409,500	40	42	18
Carmarthen	502,400	71	21	8
Caernarvon	324,700	35	54	11
Denbigh..	389,900	48	37	15
Flint	134,800	72	12	16
Glamorganshire ..	383,200	47	45	8
Merioneth	355,300	27	67	6
Monmouthshire ..	267,500	70	22	8
Montgomery	455,800	44	45	11
Pembrokeshire	356,400	60	19	21
Radnor	281,100	41	46	13
TOTAL—WALES	4,509,800	48	40	12
TOTAL—ENGLAND & WALES	30,251,000	52	18	30

STOCK PER 100 ACRES OF AGRICULTURAL LAND FOR EVERY COUNTY AND WALES

WHEAT	BARLEY	OATS	DAIRY CATTLE	OTHER CATTLE	SHEEP	PIGS	POULTRY
1939	1939	1939	1939	1939	1939	1939	1939
–	–	6	9	22	111	7	119
–	–	2	4	5	114	2	41
–	1	6	7	9	80	4	101
–	–	3	13	12	70	4	126
–	–	2	7	9	107	3	79
–	–	4	9	13	134	6	91
–	–	4	21	18	116	15	221
–	–	2	9	9	95	5	91
–	–	2	4	7	125	2	29
1	–	1	9	13	106	7	175
–	–	3	7	12	130	5	118
–	1	7	11	17	46	7	118
–	–	4	4	8	126	2	67
–	–	4	8	11	103	5	98
5	3	4	10	12	59	12	186

APPENDIX II

SKELETON FORM FOR

ESTIMATED EXPENDITURE FOR NEXT YEAR.

	Total per annum	
	Plan 1	Plan 2
	£	£
1. RENT (OR RENTAL VALUE)	......	......
2. MANUAL LABOUR	......	......
3. LIVESTOCK PURCHASES	......	......
4. PURCHASED SEEDS	......	......
5. IMPLEMENTS AND MACHINERY	......	......
6. MISCELLANEOUS EXPENSES	......	......
7. PURCHASED FOODSTUFFS	......	......
8. PURCHASED FERTILIZERS	......	......
TOTAL ESTIMATED DEBITS	£	£

1. RENT (OR RENTAL VALUE) .. ..

2. MANUAL LABOUR
   (a) REGULAR WORKERS.
   (i) Employees
   ......high pay workers @......per wk. = ...per wk. ×52 = £......for year
   ......ordinary ,, @...... ,, ,, = ... ,, ,, ×52 = £...... ,, ,,
   ......low pay ,, @...... ,, ,, = ... ,, ,, ×52 = £...... ,, ,,
   (ii) Family labour
   Self......hours per wk. @......per hr. = ...per wk. ×52 = £......for year
   Wife...... ,, ,, ,, @...... ,, ,, = ... ,, ,, ×52 = £...... ,, ,,
   Others...... ,, ,, ,, @...... ,, ,, = ... ,, ,, ×52 = £...... ,, ,,
   (b) CASUAL WORKERS.
   Root hoeing ......workers @......per week for......weeks = £......for year
   Haymaking ...... ,, @...... ,, ,, ,, ... ,, = £...... ,, ,,
   Cereal harvest ...... ,, @...... ,, ,, ,, ... ,, = £...... ,, ,,
   Root harvest ...... ,, @...... ,, ,, ,, ... ,, = £...... ,, ,,
   Threshing ...... ,, @...... ,, ,, ,, ... ,, = £...... ,, ,,
   ...... ,, @...... ,, ,, ,, ... ,, = £...... ,, ,,
   (c) INSURANCE, PERQUISITES AND EXTRAS
   Health and liability insurance = £......for year
   Overtime = £...... ,, ,,
   Bonuses (Harvest and Stockmen) = £...... ,, ,,
   Board in farmhouse = £...... ,, ,,
   ...... = £...... ,, ,,

3. LIVESTOCK PURCHASES
   (a) ......Cows, heifers and bulls @ ...... = £......
   (b) ......Store or young cattle @ ...... = £......
   (c) ......Pigs @ ...... = £......
   (d) ......Sheep @ ...... = £......
   (e) ......Horses @ ...... = £......
   (f) ......Poultry @ ...... = £......
   (g) ......Service fees @ ...... = £......

4. PURCHASED SEEDS
   (a) ......cwt. Grass seeds @ ...... = £......
   (b) ......qrs. Cereals @ ...... = £......
   (c) ......lb. Roots @ ...... = £......
   (d) ...... @ ...... = £......

5. IMPLEMENTS AND MACHINERY
   (a) New implements, machinery, and appliances = £......
   (b) Repairs to implements, machinery, and appliances = £......
   (c) Small tools, dairy utensils, plough shares, etc. = £......
   (d) Hire of steam tackle and other machinery = £......
   (e) ...... = £......

6. MISCELLANEOUS EXPENSES
   (a) ......gals. Petrol @...... : ......gals. Paraffin @...... : ......gals. Oil @...... = £......
   (b) ......tons Coal @...... = £......
   (c) Motor and van insurance, tyres and repairs ...... = £......
   (d) Horse shoeing...... = £......
   (e) ......cwt. Binder twine @...... = £......
   (f) Carriage and sack hire ...... = £......
   (g) Vet. and Medicines ...... = £......
   (h) Interest and bank charges...... = £......
   (i) ...... = £......

7. PURCHASED FOODSTUFFS
   (a) ......tons Cakes @...... = £......
   (b) ......tons Meals @...... = £......
   (c) ......qrs. Grain @...... = £......
   (d) ...... @...... = £......

8. PURCHASED FERTILIZERS
   (a) ......tons ...... @ ...... = £......
   (b) ......tons ...... @ ...... = £......
   (c) .... @ ...... = £......
   (d) .... @ ...... = £......

TOTAL ESTIMATED DEBITS .. .. .. £ £

FARM BUDGET ESTIMATE

ESTIMATED RECEIPTS FOR NEXT YEAR

	Total per annum	
	Plan 1	Plan 2
	£	£
1. LIVESTOCK SALES		
(*a*) DAIRY PRODUCE		
Total estimated yield of milk (1) .... galls. (2) .... galls.	×	×
Sales :—		
.... gallons whole milk @ .... = £........		
.... gallons whole milk @ .... = £........	....	....
.... pints cream @ .... = £........		
.... lb. butter @ .... = £........		
(*b*) HORNED STOCK		
.... cows @ .... = £........		
.... calves @ .... = £........		
.... stores @ .... = £........	....	....
.... fat cattle @ .... = £........		
.... @ .... = £........		
(*c*) PIGS		
.... fat pigs @ .... = £........		
.... stores @ .... = £........	....	....
.... sows @ .... = £........		
(*d*) SHEEP		
.... fat lambs @ .... = £........		
.... ewes @ .... = £........	....	....
.... lb. wool @ .... = £........		
.... @ .... = £........		
(*e*) POULTRY		
.... score eggs @ .... = £........		
.... birds @ .... = £........	....	....
.... chicks and hatchings = £........		
(*f*) HORSES		
.... @ .... = ...	....	....
2. CROP SALES		
(*a*) .... qrs. wheat @ .... = £........		
(*b*) .... qrs. barley @ .... = £........		
(*c*) .... qrs. oats @ .... = £........		
(*d*) .... tons seeds hay @ .... = £........		
(*e*) .... tons meadow hay @ .... = £........	....	....
(*f*) .... tons potatoes @ .... = £........		
(*g*) .... tons straw @ .... = £........		
(*h*) .... @ .... = £........		
(*i*) .... @ .... = £........		
(*j*) .... @ .... = £........		
3. MISCELLANEOUS RECEIPTS		
(*a*) Labour and machines hired out = £........		
(*b*) Grazing and foldings let out = £........		
(*c*) Shooting rents = £........	....	....
(*d*) Dung = £........		
(*e*) .... = £........		
(*f*) .... = £........		
TOTAL ESTIMATED RECEIPTS	£	£
Add estimated increase in valuation		
Subtract estimated decrease in valuation		
TOTAL ESTIMATED CREDITS	£	£

	At beginning of year	At end of year	
		Plan 1	Plan 2
VALUATIONS	£	£	£
Livestock			
Crops and tenant right			
Implements and machinery			
TOTAL VALUATION	£	£	£

APPENDIX III

SPECIMEN BALANCE SHEET AT BEGINNING OF YEAR*

Date..

Liabilities	£	s.	d.	*Assets*	£	s.	d.
Bank overdraft ..				Livestock			
Loans and Mortgages .				Crops			
				Stores			
Debts due to tradesmen and others				Implements and plant			
TOTAL B .. £				TOTAL farm live and deadstock £			
				Balance at Bank ..			
Difference between Total A and Total B, being Net Capital Value at beginning of year				Debts due from customers and others ..			
				Petty cash in hand ..			
TOTAL LIABILITIES £				TOTAL ASSETS (A) £			

* Owner-occupiers must bear in mind that the capital value of Land and Buildings, including improvements carried out during the current year, is not included amongst the Assets of these Balance Sheets. Thus to determine the real Net Capital of the owner-occupier it is necessary to add the estimated value of the property to the Net Capital value shown in these Balance Sheets.

SPECIMEN BALANCE SHEET AT END OF YEAR

Date..

Liabilities	£	s.	d.	*Assets*	£	s.	d.
Bank overdraft ..				Livestock			
Loans and Mortgages .				Crops			
				Stores			
Debts due to tradesmen and others				Implements and plant .			
TOTAL (B) .. £				TOTAL farm live and dead stock .. £			
				Balance at Bank ..			
Difference between Total A and Total B, being Net Capital Value at end of year				Debts due from customers and others ..			
				Petty Cash in hand ..			
TOTAL LIABILITIES £				TOTAL ASSETS (A) £			

SPECIMEN FARM PROFIT AND LOSS ACCOUNT

Purchases & Payments	£	s.	d.	Sales & Receipts	£	s.	d.
Cattle				Dairy produce			
Pigs				Cattle			
Chicks, hatching eggs, etc.				Pigs			
Sheep				Eggs and poultry			
Horses				Sheep and wool			
Service fees				Horses			
Dairy and poultry produce bought for resale				Service fees			
Labour				Wheat			
Feeding-stuffs				Barley			
Fertilizers				Other corn			
Coal, oil, etc.				Beans and field peas			
Contract cultivations, etc.				Sugar beet			
Purchases of and repairs to equipment				Potatoes			
Seed				Market garden crops			
Road and rail transport				Hay, straw and small seeds			
Miscellaneous expenses, including rent				Miscellaneous receipts			
TOTAL EXPENSES FOR YEAR £				TOTAL SALES FOR YEAR £			
				Add (1) Estimated value of farm produce, etc., used by household			
Add Valuation of farm live and deadstock per opening Balance Sheet				(2) Valuation of farm live and deadstock per closing Balance Sheet			
TOTAL A £				TOTAL B £			
BALANCE (when B exceeds A) being NET PROFIT from farm £				BALANCE (when A exceeds B) being NET LOSS from farm £			
TOTAL £				TOTAL £			

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